PHYSICS

Questions book II

Nuffield Physics
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PQB 04202

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Published for the Nuffield Foundation by
Longmans/Penguin Books

First published 1966
Reprinted with corrections 1967

Longmans, Green and Co Ltd,
48 Grosvenor Street, London, W.1
Penguin Books Ltd,
Harmondsworth, Middlesex

Made and printed in Great Britain by
Richard Clay (The Chaucer Press), Ltd,
Bungay, Suffolk

Set in Monotype Plantin

Designed by Ivan and Robin Dodd

FOREWORD

This volume is one of the first to be produced by the Nuffield Science Teaching Project, whose work began early in 1962. At that time many individual schoolteachers and a number of organizations in Britain (among whom the Scottish Education Department and the Association for Science Education, as it now is, were conspicuous) had drawn attention to the need for a renewal of the science curriculum and for a wider study of imaginative ways of teaching scientific subjects. The Trustees of the Nuffield Foundation considered that there were great opportunities here. They therefore set up a science teaching project and allocated large resources to its work.

The first problems to be tackled were concerned with the teaching of O-Level physics, chemistry, and biology in secondary schools. The programme has since been extended to the teaching of science in sixth forms, in primary schools, and in secondary school classes which are not studying for O-Level examinations. In all these programmes the principal aim is to develop materials that will help teachers to present science in a lively, exciting and intelligible way. Since the work has been done by teachers, this volume and its companions belong to the teaching profession as a whole.

The production of the materials would not have been possible without the wholehearted and unstinting collaboration of the team members (mostly teachers on secondment from schools); the consultative committees who helped to give the work direction and purpose; the teachers in the 170 schools who participated in the trials of these and other materials; the headmasters, local authorities, and boards of governors who agreed that their schools should accept extra burdens in order to further the work of the project; and the many other people and organizations that have contributed good advice, practical assistance, or generous gifts of material and money.

To the extent that this initiative in curriculum development is already the common property of the science teaching profession, it is important that the current volumes should be thought of as contributions to a continuing process. The revision and renewal that will be necessary in the future, will be greatly helped by the interest and the comments of those who use the full Nuffield programme and of those who follow only some of its suggestions. By their interest in the project, the trustees of the Nuffield Foundation have

sought to demonstrate that the continuing renewal of the curriculum – in all subjects – should be a major educational objective.

Brian Young
Director of the Nuffield Foundation

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To those on whom these problems are inflicted

First of all, don't worry.

You will probably be able to answer some of the problems. Others you will find too difficult. Some, you will find, have no simple answer: this in intentional, but see what you can do. And some problems are simply meant to start discussion – they ask, 'What do you think?'

Some problems will involve things you have already covered in your physics. Others will bring in new topics. And some problems will be concerned with things which are unfamiliar but which are linked with what you have already heard about. Some questions are just problems to test your ingenuity. A good scientist tests what he can, and what he has time for, but he cannot test everything, he cannot find all the answers. All the same, he enjoys speculating about – wondering about – a lot of other things.

Altogether there are far too many problems for you to be able to tackle all of them. You will have to pick and choose. Some problems will be more interesting, or provoking, than others. Do them. With luck, you will enjoy them.

Above all, don't worry.

1 More about forces

1 Listed below are a number of ways in which a force can be exerted. For each of these *give*, in one sentence, *an actual example of the kind of force mentioned.* (For example, under (*a*) I might say 'e.g. when I start to walk I push backwards on the ground with my foot'.)

a. Motion: force exerted by something starting to move, e.g. . . .
b. Motion: force exerted by something slowing down (or stopping), e.g. . . .
c. Motion: force exerted by something moving whose direction of motion is being changed (without noticeable change of speed), e.g. . . .
d. Tension: force exerted by a stretched solid material, e.g. . . .
e. Compression: force exerted by a compressed solid, e.g. . . .
f. Compression: force exerted by a compressed liquid, e.g. . . .
g. Compression: force exerted by a compressed gas (or air), e.g. . . .
h. Friction: solid moving over, or through, a liquid, e.g. . . .
i. Friction: solid moving over another solid, e.g. . . .
j. Gravitation: e.g. . . .
k. Electrostatic: force exerted by electric charges at rest, e.g. . . .
l. Magnetic: force exerted by magnets, e.g. . . .
m. Magnetic (or 'electromagnetic'): force exerted by current in a wire, on a magnet, or one circuit on another circuit, e.g. . . .
n. Surface tension: force exerted by a liquid film or skin, e.g. . . .
o. Expansion: force exerted by something being heated, e.g. . . .
p. Contraction: force exerted by something allowed to cool, e.g. . . .
q. Any other sort of force that does not come under any of the above headings.

2 Here are some ways in which *you* exert forces. You are asked to say what you notice about these forces; that is, how they alter as you go on pushing, pulling, or twisting. The first two are given as examples.

a. Stretch elastic (e.g. part of garment, sewing elastic, elastic used for catapult). Observation: pull increases the more you stretch.

Note to teacher: These questions are to be answered orally round the class. Leave out any that are too difficult. If there are not enough to go round the class, start again with the same questions asking for different examples.

b. Turn on tap. Observation: tap is tight at start, then becomes easy to twist, then tight again.

Not all elastic, taps, etc., behave in the same way, so your answer and that of another boy or girl are not necessarily the same. Now give *your* answers to (*a*) and (*b*), then go on from (*c*) to (*n*) below.

c. Turn off tap.
d. Pull out drawer.
e. Push in drawer.
f. Pull up a tough, deep-rooted weed.
g. Dangle a cord over the edge of the stairs and attach it to a chair, stool, or other convenient heavy object. Then pull up slowly.
h. Push the top of the backrest of a chair so as to tilt it on its back legs more and more. The chair should be on a carpet, or other means should be used to make sure it does not slide.
i. Find an empty bottle, cork it, and slowly sink it deeper and deeper under water in a pail or sink or water butt.
j. Try pushing the uncorked bottle under water, neck upwards.
k. Now try pushing the uncorked bottle under water so that it fills, then slowly lift it out, neck upwards.
l. Hold the uncorked bottle under water so that it fills, then slowly lift it out, neck *downwards*.
m. Wind up a clock – very gently!

3 Five effects or results a force can produce are listed below. Copy the list and add one example to illustrate each, e.g. after (*a*) we might add: 'A sailing yacht: the wind freshens and exerts a greater force (pushes harder) on the sails so that the yacht moves more quickly.'

Note: acceleration means 'going faster', 'increasing speed'.

a. Acceleration in a straight line: a force can start a body moving and increase its speed, e.g. (give an example different from the one about the yacht).
b. Acceleration in a circle: a force can start a body rotating and increase its speed of rotation, e.g. . . .
c. Slowing down or stopping, of objects moving in a straight line or of objects rotating, e.g. . . .
d. Opposing other forces so as to keep something at rest, e.g. . . .
e. Balancing other forces so as to keep something moving with constant speed, e.g. . . .
f. Deformation of an object's size or shape or both, e.g. . . .

4 A man steps off a moving bus and falls heavily. In what direction does he fall and what force or forces caused him to fall? (He is a rather silly man, but you can assume he was sensible enough not to hold on to the bus as he stepped off!)
This man provides *two* examples of effects or forces listed (*a*) to (*f*) in question 1. Which two?

5 Long ago a party of soldiers attacked a castle gate with a battering ram. That is, they carried a huge log of wood on their shoulders and ran with it up to the gate so that the log bashed the gate and broke it. Just before the log hit the gate the men stopped holding the log and left it loose to slide on their shoulders. *Why*? What would happen to a man who held on to it?

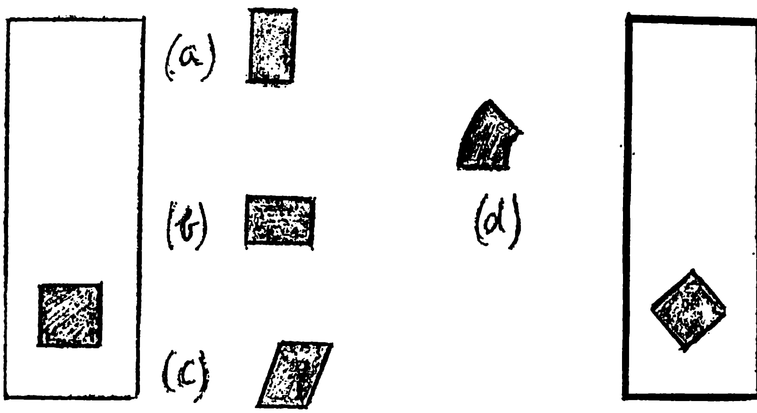


Figure 6(*i*) and (*ii*)

6 (*i*) Figure 6 (*i*) shows a square drawn on a short piece of thick rubber tubing. The tubing is vertical and is fastened at the lower end.

a. A force is applied to the upper end, and the square is seen to be distorted into the rectangle. What was the direction of the force?
b. A force applied at the top, but in a different direction, produced the shape (*b*). What was the direction of this force?
c. How can a distortion of the square into the shape shown in (*c*) be produced?
d. How can the shape shown in (*d*) be produced?

(*ii*) Figure 6 (*ii*) shows another square drawn on the same piece of rubber tubing. The tubing is distorted in the same way as in (*a*) above. What shape does *this* square take? Try it.

7 A bicycle wheel which can spin freely with very little friction is mounted vertically free to rotate with its axle on a firm support. The wheel is clear of the ground and at first it is at rest. A boy catches hold of the top part of the rim and pushes it straight ahead and starts the wheel spinning.

a. Draw a sketch of the wheel and show on it the horizontal force exerted by the boy, and all the other horizontal and vertical forces acting on the wheel.
b. The wheel spins but does not move away from its position; what does this tell us about the sum of all the horizontal forces? About the sum of the vertical forces?
c. Why do the horizontal forces make the wheel spin while the vertical forces do not?
d. How could the boy start the wheel spinning by means of a vertical push? And where is the other vertical force, which balances the push of the boy?
e. Suppose that, instead of being in a fixed support, the wheel is fixed to an axle (which must turn with it) and the axle rests on horizontal rails. What happens now when the boy exerts a horizontal force on the top of the rim?

Note: The bicycle wheel, question 7, and the pulley, question 8, are supposed to be very free-running, that is, they are practically frictionless.

8 *Very hard.* A 70-kg man stands on a 30-kg platform.

a. What force does the man have to exert on the rope to hold himself and the platform up?
b. Freddie says the answer to (*a*) is 100 kg. Freddie is wrong as usual. Why is this obviously wrong?
c. Suppose the man weighs 49 kg and the platform 51 kg. What happens?

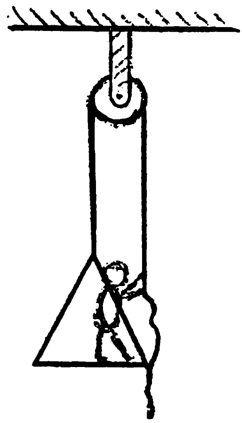


Figure 8

9 Freddie Jones says there is no advantage in using two engines to pull a train, because you can't get two engines that are equally strong. If used separately one engine must pull the train faster than the other. The addition of the slower engine could then only slow down the train. What do you say?

10 Two powerful horseshoe magnets are mounted one on each of two small trucks, with the open ends of the magnets facing each other.

a. Describe what may happen when the trucks are pushed in a straight line towards each other. One magnet is then turned over and refixed on its truck. What difference does this make when the trucks are pushed together?
b. How would you use pieces of sponge rubber and a length of elastic (instead of the magnets) to show a similar effect with the trucks?
c. The similarity between (*a*) and (*b*) is confined to the fact that attraction and repulsion can be demonstrated with the magnets and with rubber and elastic. Say what differences there are (*i*) between

the attraction due to two magnets and the 'attraction' due to a piece of stretched elastic, and (*ii*) between the repulsion due to two magnets and the 'repulsion' due to two pieces of sponge rubber.

11 *a.* Say how you would find which is the North-seeking pole of a magnet and which the South, without making use of any other artificial magnet.
b. How would you show the truth of the rule about forces between poles, i.e. 'like poles repel: unlike poles attract'?

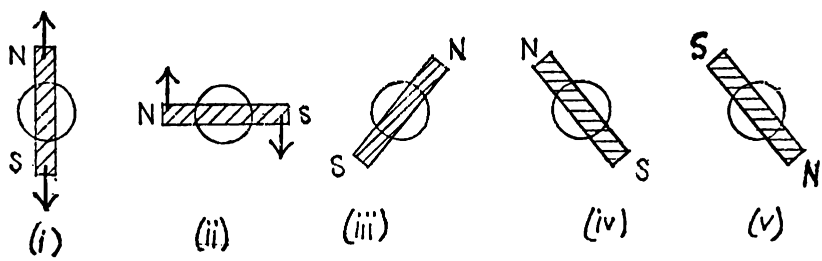


Figure 12

12 The five diagrams above show five positions of a short bar magnet which is placed on a flat piece of cork and then floated on water in a glass trough. The arrows in (*i*) and (*ii*) show the forces, due to the Earth's magnetism, which act on the magnet when it is placed in these two positions.

a. Copy the diagrams and add suitable arrows to (*iii*), (*iv*), and (*v*).
b. The magnet in figure 12 (*i*) stays in this position and does not move in any way. What does this tell us about the poles of the magnet?
c. Give the reason for your answer to (*b*).
d. Write against your diagrams (*ii*), (*iii*), (*iv*), and (*v*) the words 'clockwise' or 'anticlockwise', according to whether you think the magnet will turn in the same direction as the hands of a clock or in the opposite direction.

2 Electric currents. Simple circuits

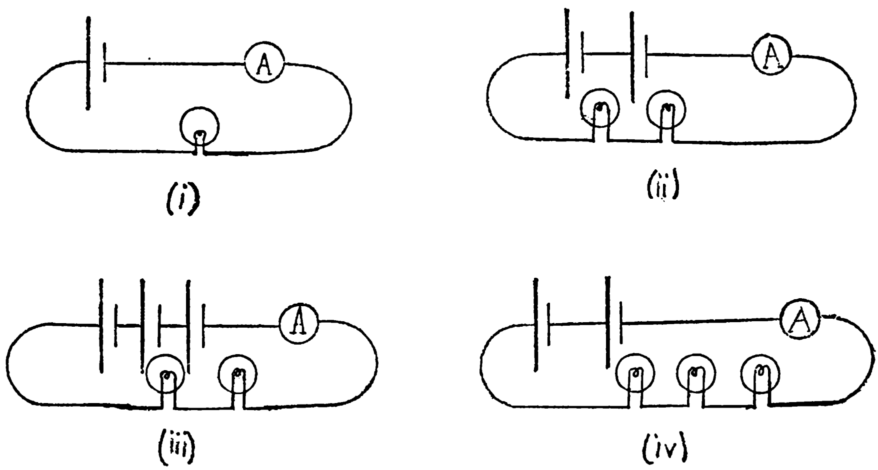
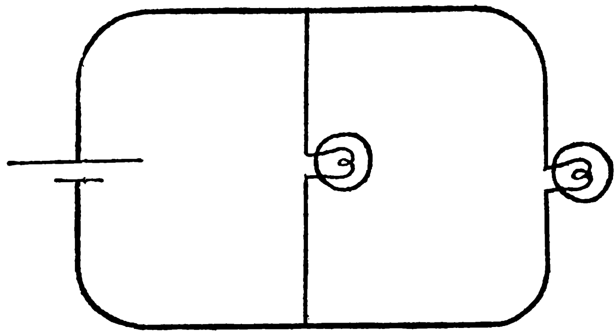


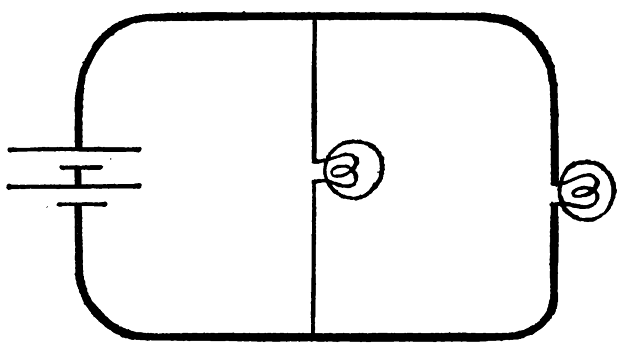
Figure 13

13 The four drawings each show circuits containing one or more ammeters, batteries, and lamps.

a. Which symbol means an ammeter, which a lamp and which a battery? Answer by drawing circuit (*i*) and labelling the three items shown.
b. How is the positive end of the battery shown in the symbol?
c. Are the lamps in the last three drawings in series or in parallel?
d. If the lamp in (*i*) is at full normal brightness, what about the lamps in (*ii*), (*iii*), and (*iv*)? Are they brighter or less bright than that in (*i*)?
e. In which circuit would the batteries run down most quickly?
f. Draw circuit (*iv*) and include a switch that would turn off the lamps without any wires having to be disconnected.



(a)



(b)

Figure 14

14 (*i*) Are the lamps in figure 14 (*a*) and (*b*) in series or in parallel?
(*ii*) Are the lamps in (*a*) at normal brightness, or less bright, or more bright than normal? What about (*b*)?
(*iii*) In which circuit would the batteries run down more quickly?
(*iv*) Draw circuit (*a*) and include three switches, one to turn off both lamps together, one to turn off one lamp only, and one to turn off the other lamp only.

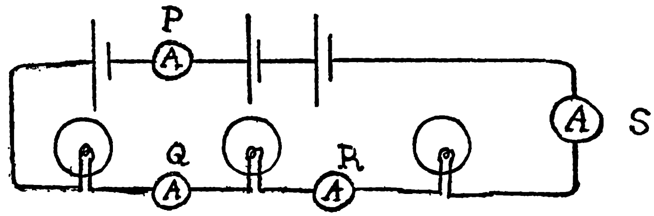


Figure 15(*a*)

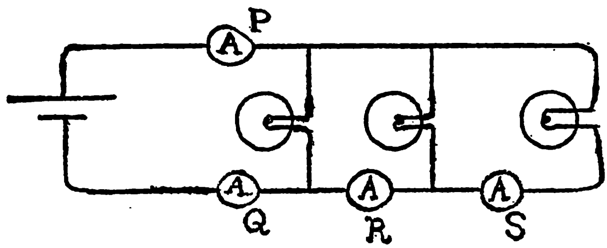


Figure 15(*b*)

15 (*i*) Figure 15 (*a*): if ammeter Q reads 1·5 units, what do ammeters P, R, and S read?
(*ii*) Figure 15 (*b*): if ammeter S reads 1·5 units, what do P, Q, and R read? Assume that the lamps are all alike and that the ammeters read correctly.

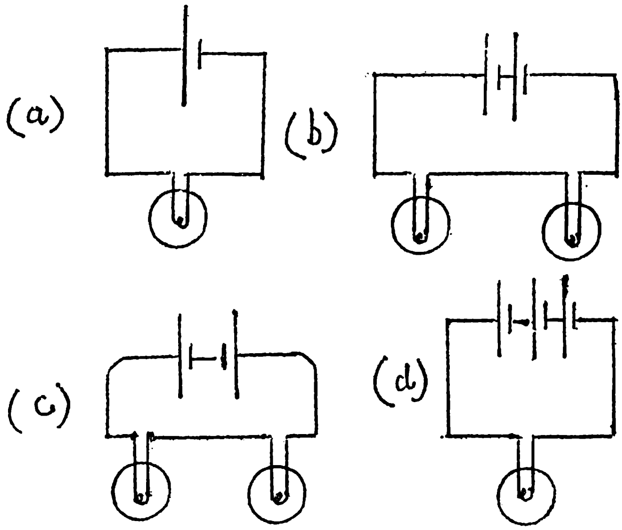
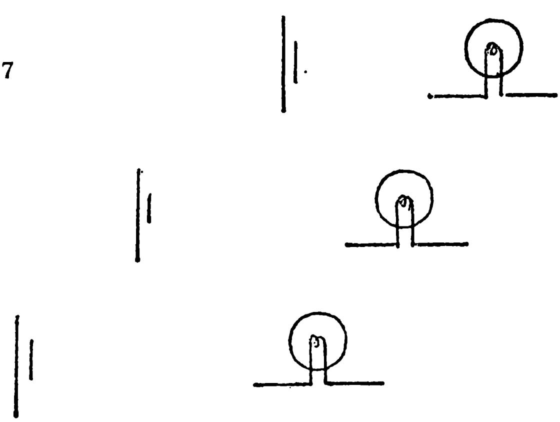


Figure 16

16 (*i*) The lamp in circuit (*a*) is normally bright. What can you say about the brightness of the lamps in (*b*)? In (*c*)?
(*ii*) What is almost certain to happen if circuit (*d*) is joined up? Explain the use of a *fuse* to prevent damage if a circuit like (*d*) is connected by mistake.

17 *a.* Draw lines to show how you can connect up the three torch bulbs and batteries so that the lamps are all in the same circuit and all fully lit.

Figure 17



b. Make a sketch to show how you could arrange for all three torch bulbs to be lit fully from one battery only.

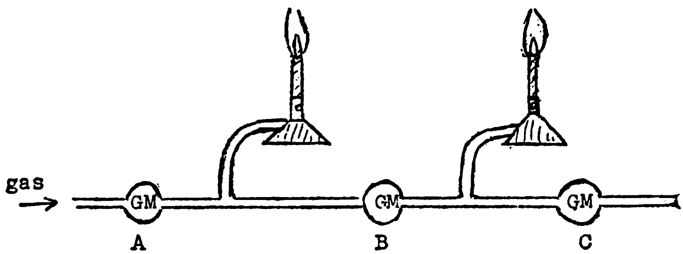


Figure 18

18 *a.* If the gas-meter B reads $1\frac{1}{2}$ cubic feet per minute, what do meters A and C read?
b. How many pipes are taken from gas mains to a gas-stove, and how many wires from electric mains to an electric-stove? (Two answers to the last part, one good and one very good – if you can explain the very good answer.)

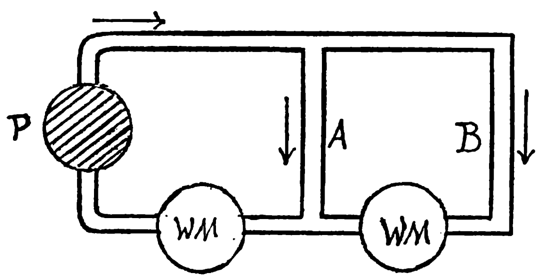


Figure 19(*a*)

19 *a.* Figure 19 (*a*) shows a water pump P driving water through two narrow pipes A and B, and two 'water meters' WM. Draw an electric circuit containing a battery, two lamps, and two ammeters, which is similar to the water circuit 19 (*a*).

b. Draw a water circuit, containing a water pump, a water meter, and two narrow pipes, which is similar to the electrical circuit figure 19 (*b*).

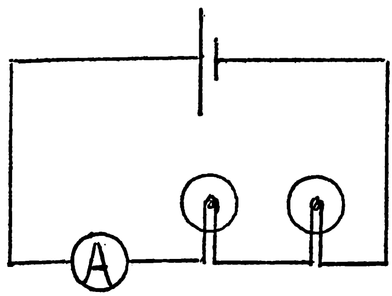


Figure 19 (*b*)

20 You have used a simple current-balance to measure currents in units, and you have seen ammeters which have specially marked scales measuring in 'amperes'.

a. What are the advantages of measuring in amperes rather than in your current-balance 'units'?
b. You could make marks on your current balance, for currents of '1 lampsworth', '2 lampsworth', etc. How would you find out, by experiment, what those marks on your current-balance correspond to in amperes? (You may use a suitable ammeter and other usual apparatus.)

21 The three diagrams of figure 21 show (*a*) flow of water with water-flow meters, (*b*) flow of traffic, with three persons counting the cars per hour passing on each road, or with some automatic traffic-flow meter, and (*c*) wires carrying electric currents, with ammeters.

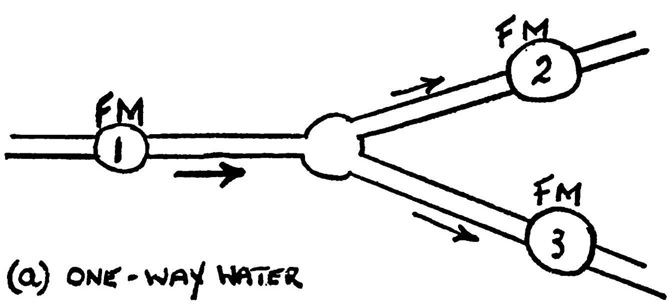


Figure 21(*a*)

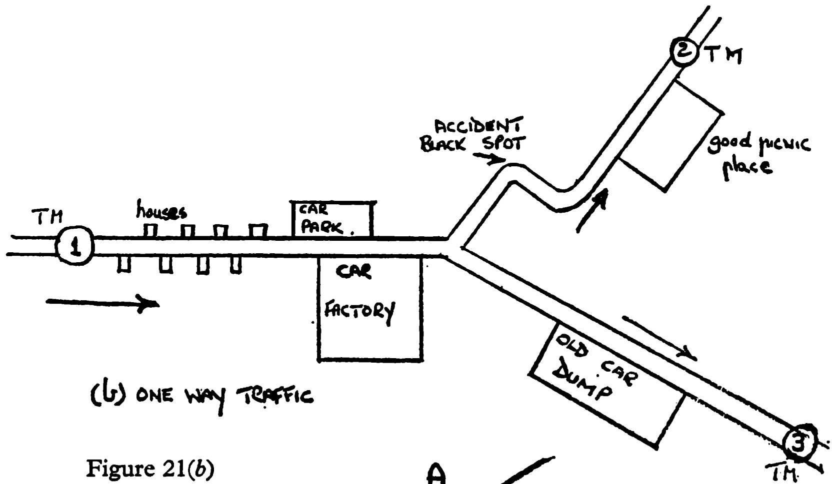


Figure 21(*b*)

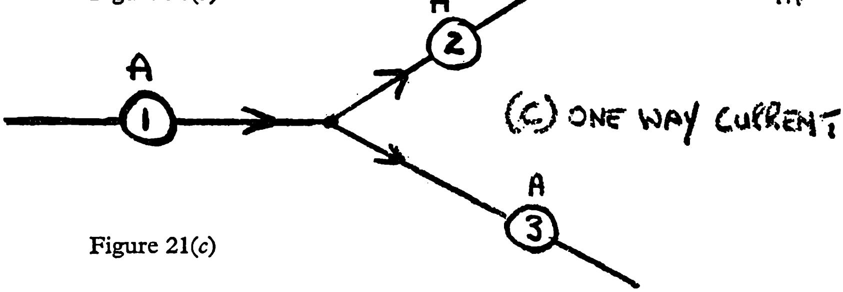


Figure 21(*c*)

a. Figure 21 (*a*): we expect that the reading of flow-meter 1 equals that of the other two together, i.e.

$$FM_1 = FM_2 + FM_3$$

What commonsense assumptions do we make about water, which leads us to expect this result?

b. Figure 21 (*b*): is it also true that TM 1 = TM 2 + TM 3? Answer 'yes' or 'no', and write a sentence or two in explanation.
c. Figure 21 (*c*): does this resemble the water in (*a*) or the traffic in (*b*)? What, then, do we assume about electricity in circuits of the kind you have used so far?

Note: We have supposed that the water, or the cars, or the electricity go one way only. This is true for the water; but traffic can be two ways at the same time, and usually it is. For all we know at this stage, an 'electric current' might be two different sorts of electricity flowing opposite ways, like ordinary traffic instead of one-way traffic. We shall find out about this later, but even if electric current is 'two-way', the arguments in this question would not be upset, though they would be made more complicated.

3 Resistance. Batteries and ammeters

22 Here are two new electrical symbols:

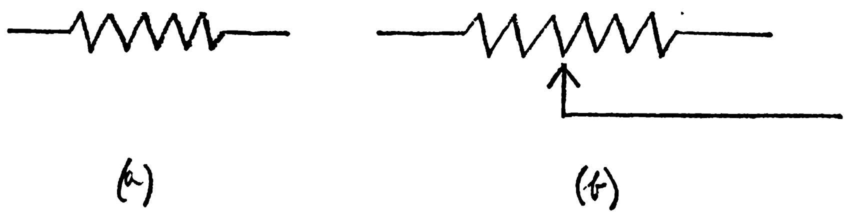


Figure 22

What do they represent? Describe (one sentence for each) something that you have used that can be represented by symbol (*a*) and something by symbol (*b*).

23 In the diagram, S is a switch.

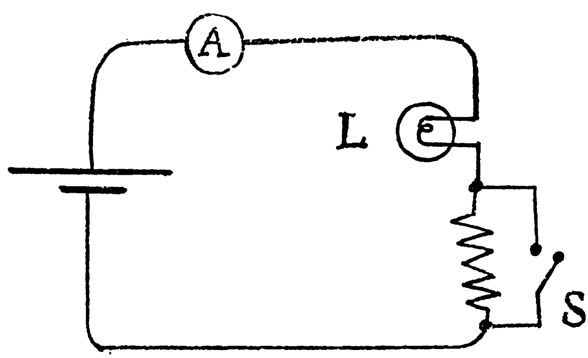


Figure 23

a. What happens to the brightness of the lamp L and the current shown by the ammeter, A, as the switch is opened and closed?
b. The ammeter, A, reads 1 ampere with the switch closed and 0·5 ampere with the switch open. What has happened to the other 0·5 ampere? Has it gone anywhere?

24 *a.* In the circuit shown, the ammeter at A reads 1 ampere with the switch open (off) and 0·9 ampere with the switch closed (on). What has happened to the other 0·1 ampere? (In this case the resistance of R must be quite small because the resistance of the ammeter is very small anyhow.)

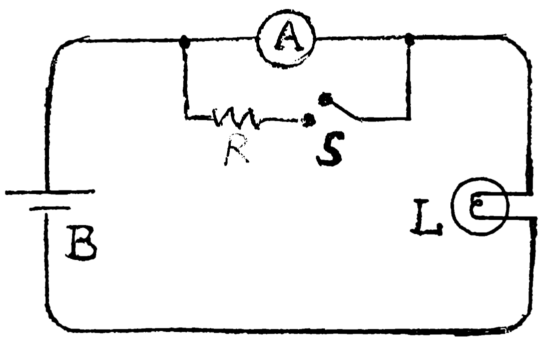


Figure 24

b. A second ammeter is joined in the circuit at B, next to the battery. This ammeter does not noticeably change its reading when S is opened and closed. Why not?

25 *a.* Draw the circuit of figure 25 (*a*), including a 'dimmer' that would dim lamp L_2 without affecting L_1.

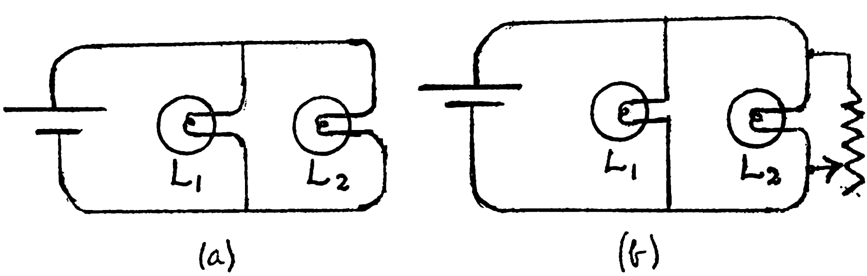


Figure 25

b. In answer to part (*a*) of this question, Freddie Jones drew circuit 25 (*b*). Why is this a 'fool's circuit', and what would be the bad results of using it?

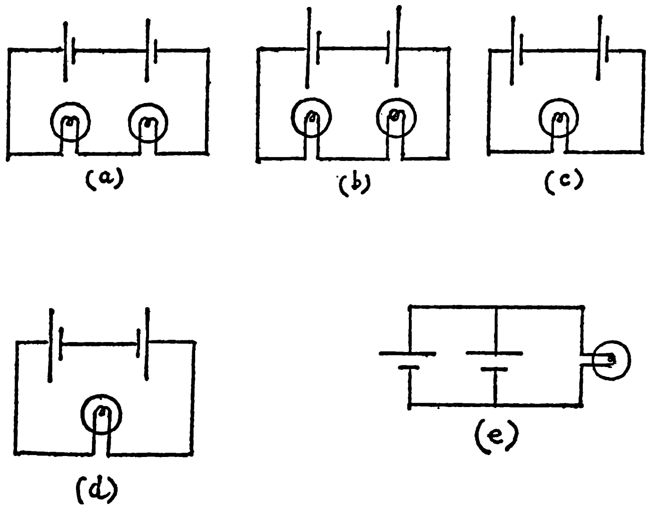


Figure 26

26 Figures 26 (*a*) to (*e*) show circuits containing similar lamps and similar batteries. Say for each circuit whether the lamps are normally bright, overrun, underrun, or no current at all. (One battery lights one lamp with 'normal' brilliancy.)

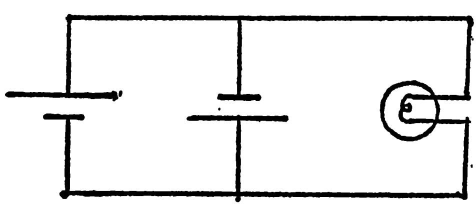


Figure 27

27 Figure 27 shows another 'fool's circuit' Freddie joined up. Why is this a fool's circuit and what would be the result of using it?

28 So far in these problems we have not bothered very much with direction of current. In future we shall adopt a universal agreement made a century ago. We shall say that something which we call 'the current' runs from the '+' terminal (the red one) of the battery, round the circuit to the '—' terminal (the black or blue one) of the battery. We put arrow heads on the circuit diagram to show the direction of that current.

Suppose there is some 'positive' (+) electricity. (+) that is stored up at the + end of the battery, ready to move round the circuit. *If* that positive electricity does move round the circuit it must travel in the direction shown by the arrow heads.

a. But *perhaps* the current in the wire is *not* really a flow of that positive electricity. What other kind of current can you imagine instead? There are two other possibilities, besides the flow of positive electricity we have just described. Can you think of both? What arrow heads would you put for each of those suggestions? (One of those suggestions is what we now think happens in real wires, but electrical engineers and scientists agreed long ago on the arrow heads pointing from positive to negative, that we have shown in the diagram here. It would be too confusing to change over to some other arrangement now.)

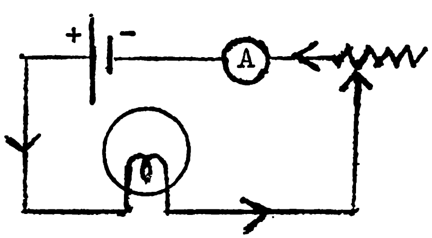


Figure 28

b. In the diagram (figure 28) there are *four* arrow heads. Three show the 'direction' for the current; the fourth does not. Which is the fourth arrow head and what is it doing in the diagram?

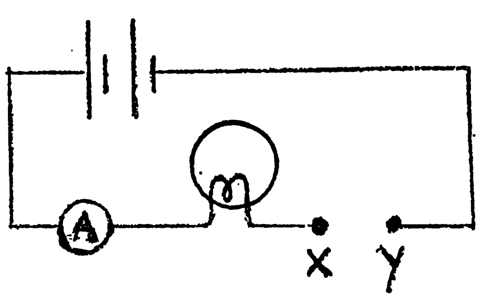


Figure 29

29 In your laboratory work you set up a circuit like figure 29 and joined various things between two metal pillars X and Y. Mention four of the more interesting things you joined between X and Y, and say what happened in each case. (Not liquids; question 33 is concerned with liquids.)

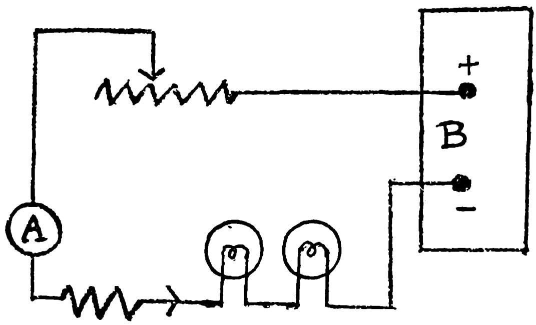


Figure 30

30 B is a box containing a battery, with two terminals. The battery consists of several cells, and it is supplying current to the circuit shown (figure 30). You have a voltmeter that reads '1·4 volts' for a single cell. How would you use the voltmeter to find the number of cells in the battery?

Copy the diagram and show how you would connect the voltmeter.

31 The mains supply is said to be 240 volts. How many 1·5-volt flashlamp cells would be needed to obtain 240 volts and how would they be connected? If you had this number of cells and joined them together in this way, why would they not be a suitable substitute for the mains supply? What would happen if you tried to use such a battery to light mains bulbs and to work an electric fire?

32 *a.* Draw a water-pump circuit with two narrow tubes in series with wider tubes. Water is forced through the tubes by the pump. Include in the circuit a water-flow meter to measure the water current and a pressure gauge to measure the pressure difference *between the ends* of *one* of the narrow tubes.

b. Draw an electric circuit similar to (*a*) consisting of a battery joined to two resistors in series. Show on the circuit where you would connect an ammeter to measure the current and where you would connect a voltmeter to measure the 'electrical pressure difference' across one of the resistors.

c. 'Electrical pressure difference' is put in inverted commas because that is not the right name for this quantity; it has been called that because it seems to be rather like 'water pressure difference'. What is the correct name, and in what units is it measured?

4 Electric currents in liquids (electrolysis)*

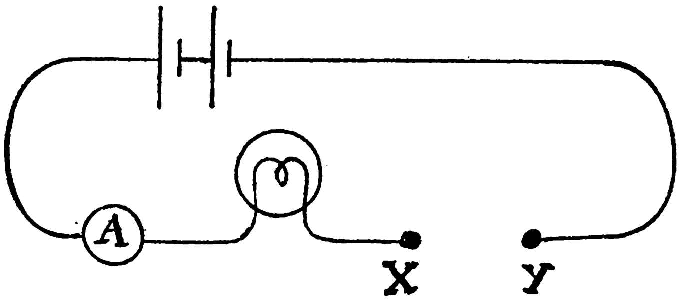


Figure 33

33 Draw the circuit (figure 33) and add to it two wires leading from the pillars X, Y into a liquid in a beaker. Say what you saw happening: (a) when the liquid was pure distilled water, (*b*), (*c*), (*d*) when you used three other liquids or solutions (say which).

Why is it important that the wires in the beaker should not touch each other?

34 Look back to your answer to the previous question.

a. Now redraw your circuit diagram and add arrows to it, to show the 'official' direction in which 'positive' current flows.

Does it flow, according to the standard agreement from X to Y or from Y to X?

b. Does the fact that we use this agreement mean that it must be true, that is, does it mean that there must be actual positive particles of electricity (or perhaps positive 'juice') flowing round the circuit? If not, why do we use it?

35 For the purpose of this question let us forget about the agreed current direction (question 34) and speculate about (wonder about) what *actually* happens in some of the liquids we have used in the beaker containing the wires from X and Y.

* In Year II we suggest only a brief introductory treatment of electrolysis. Some of the questions in this Section ask more than will be covered by an average group.
Schools following the Nuffield Chemistry programme will find that electrolysis is covered more fully in chemistry.

a. First, say what is observed when the beaker contains copper sulphate solution. Does the copper get deposited on the wire joined to X or on that joined to Y? Which way is the copper going through the solution?
b. Suppose the copper carries electricity with it. Which way is the electricity going, in the direction of the arrows you have already put on the wires or against that direction? Which sort of electricity, positive or negative, is carried by the copper?
c. Next, what happens when the beaker contains water acidulated with a little sulphuric acid? What comes off at X, and what at Y?
d. What does this suggest about the way in which the electricity is carried in the acidulated water? Which sort of electricity, positive or negative, is carried by the hydrogen? By the oxygen?

Important note. We now have the suggestion that, in some solutions that carry current, the current may consist of positive and negative electricity carried by material substances in the solution (such as copper, hydrogen, oxygen), and travelling in opposite directions at the same time.

However:
1. This is only a suggestion, which certainly fits the very small amount of experimental evidence we already have; but we need a great deal more evidence before we finally accept it.
2. It still tells us nothing about what goes on in the connecting wires.
3. Even if we adopt this suggestion as a useful supposition, we still shall not abandon the conventional 'positive current' that you wrote about in answer to question 34.

36 What name is given to the particles which we suppose to carry the current in some solutions (e.g. copper in copper sulphate solution)? What does the name mean in the original Greek? Why do you think this new name is chosen, rather than just calling them 'copper atoms' or 'copper molecules'?

37 *a.* Describe very briefly some observations you have made on electric currents passed through pieces of paper moistened with various solutions. (Write a sentence or two about the apparatus used, and a sentence to describe each observation.)
b. These experiments are interesting though not very important – however, pieces of 'moistened-paper' might serve some useful purpose – what do you suggest?
c. What do 'd.c.' and 'a.c.' stand for? How do you think a.c. differs from d.c.?

38 You have used current-measuring instruments depending on the magnetic effect of an electric current, namely, ammeters and your simple type of 'current balance'.

Briefly outline a possible method of measuring electric current by its 'chemical effect' of depositing copper from a solution of copper sulphate.

5 Electricity in gases

39 *a.* How do you know, without doing any further experiments, that air must be a very good insulator? Mention two or three of the curious things that would happen if, by waving a wand, the air around us suddenly became conducting.
b. Freddie Jones says, 'Yes, that's all very well for air, but it doesn't prove that other gases are insulators.' How would you discover whether carbon dioxide is an insulator, given a cylinder from which the gas could be obtained?

40 Air and other gases are very good insulators under ordinary conditions, that is, room temperatures, and with batteries or the electric mains as sources of current. Under other conditions gases may become conducting.

Describe experiments which demonstrate air or some other gas carrying electricity. (Show the apparatus in a sketch and then write a sentence or two to say what happened.)

41 Two types of electric lamps are in common use in houses and in larger buildings: the 'tungsten-filament' lamp, and the 'fluorescent' lamp. Find out what you can about these lamps, both by looking at some and from diagrams in books (do not trouble with any of the more difficult information given in the books).

Now write about six sentences comparing the two types of lamp, and answering questions such as: Where does the light come from; does the current go through solid, liquid or gas; how do the colours of the light from the two lamps compare; what about the temperature of the outside surface of the lamps as felt by hand?

6 Electricity in a vacuum*

42 You have seen in the laboratory a clear glass apparatus with a very good vacuum inside it. By means of a special apparatus called an 'electron gun', electricity can be shot through the tube.

a. Imagine a similar 'thought experiment' that might be done with (*i*) a rifle firing bullets and (*ii*) a powerful hose 'firing' water or molten metal. Describe your experiment in a few sentences and say what you think you would expect to see.

Note: *Better try it in a tunnel rather than a glass apparatus!*

A thought experiment is one which you do in your head! It is an experiment which you think could possibly be done, though it might be very difficult to make the apparatus. But you do not think it necessary to do it because just thinking about it helps you to sort out your ideas.

b. Does the fact that we can use a kind of gun to shoot electricity into a vacuum mean that electricity must be made up (consist) of particles ('bullets')? Write a sentence or two in explanation.

43 *Following the last problem.* Freddie Jones says that the electricity from the gun cannot consist of particles; it must be a stream of something like water, 'because,' he says, 'if there were particles we should see a flickering effect, a series of "blips", where the electron beam hits the glass. We don't, we see a continuous light, therefore the beam must be continuous.' What do you say to this?

44 You have seen, first a large clear glass bulb with an electron gun inside, and later, a 'cathode ray oscilloscope' also containing an electron gun.

a. You could actually 'see' the beam inside the first of these, but not in the oscilloscope. Yet it is the same kind of electron beam in both. How do you explain the difference?
b. On the other hand, the spot on the oscilloscope where the beam ends is much brighter; why is this?
c. Which of the two tubes you have seen in the laboratory has the greater resemblance to a television tube?

* Except with a very fast group, Questions 45–47 should be postponed to Year IV.

d. It is dangerous to fiddle around inside a radio receiver which is still connected to the electric mains. Why is it even more dangerous to do this with a television receiver?

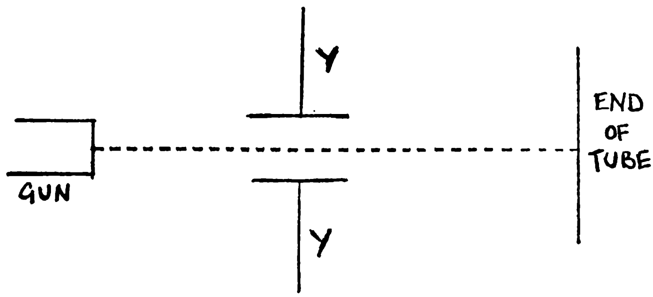


Figure 45

45 Figure 45 is a much simplified diagram of an electron beam in a cathode ray oscilloscope, coming from an electron gun, and making a light spot on the end of the tube, in the way you have seen. YY are two plates that can be joined to a battery. Note that these plates cover only a small portion of the beam's path.

a. A battery is joined across the plates YY so that the beam is deflected upwards. Draw a diagram like figure 45, but showing the battery and the deflected path of the beam. Remember that only the part of the beam's path that lies between YY will be noticeably curved.
b. The battery connections to YY are reversed; draw the path of the beam now.
c. A transformer giving alternating voltage is now joined to YY, and the maximum deflection this gives is the same as we had with the battery. Shade in your diagram all the possible positions of the electron beam when the transformer is being used.
d. What would we see on the screen at the end of the tube in (*a*) above? in (*b*)? in (*c*)?

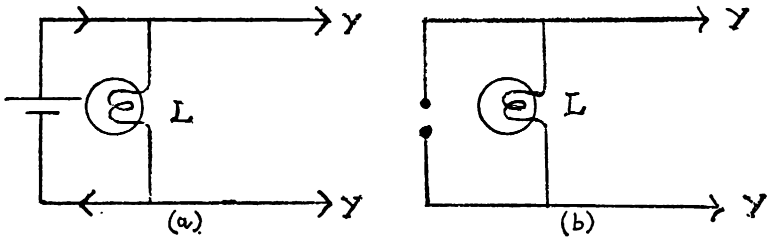


Figure 46

46 A battery was joined (figure 46 (*a*)) to a lamp L and also to the YY plates (figure 45) of a cathode ray oscilloscope, so that the light spot was displaced. A transformer supplying alternating current was then joined to the lamp in place of the battery (figure 46 (*b*)). This gave a line of light on the screen, and this line was found to be equal in length to the displacement of the spot that was produced by the battery.

Although the two oscilloscope deflections with d.c. and a.c. were equal, yet it was noticed that the lamp was considerably less bright on the a.c. supply. How can this be explained?

47 A single cell is joined across the deflecting plates of a cathode ray oscillograph and the light spot is displaced 0·75 cm.

a. How far will the spot be displaced if, instead of a single cell, two cells in series are joined to the deflecting plates? three cells? four cells?
b. Can we say, then, that the cathode ray oscillograph is a kind of ammeter? or a kind of voltmeter?
c. What is it in the oscilloscope that corresponds to the pointer in the meter?
d. Give one disadvantage, and one advantage, of the oscilloscope compared with the meter, when used for measurement such as (*a*) above. (You can think of measurements made with sources of a.c. as well.)

48 An oscilloscope can be used for measurements, as in question 47, but more often it is used simply to show us things – 'pictures' – if you like.

What picture of alternating currents can it show us? Write a sentence or two explaining how the oscilloscope is made to do this.

7 Electrostatics

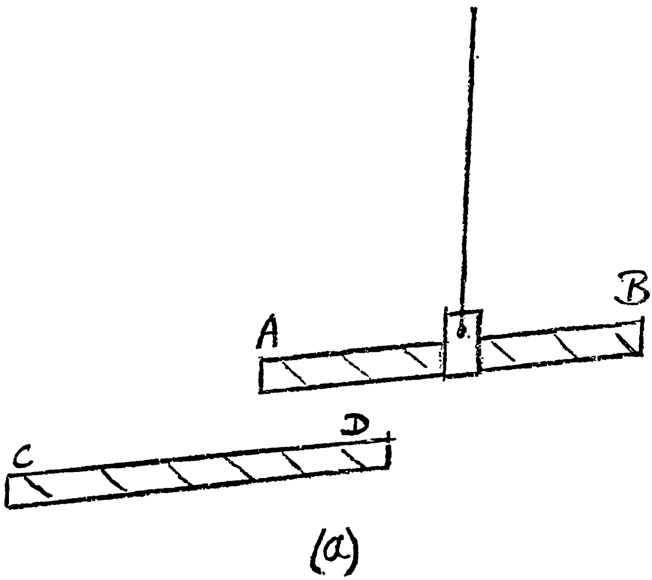


Figure 49(*a*)

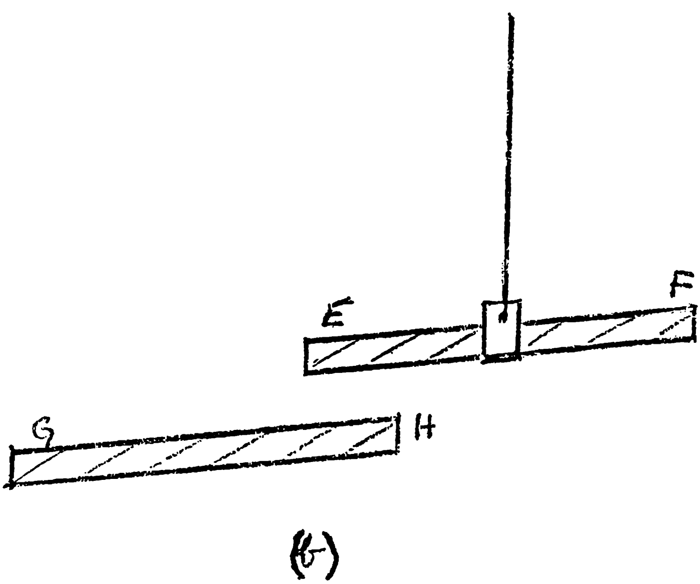


Figure 49(*b*)

49 *a.* A strip of 'cellulose acetate' AB is supported in a paper stirrup, figure 49 (*a*), the stirrup being attached to cotton or nylon thread and supported in any suitable way. This acetate strip is then 'charged' at both ends by rubbing it with tissue-paper. A similar acetate strip CD is also charged at both ends.

The end D is brought close to A, then to B. Then C is brought up to A and then to B – four different observations.

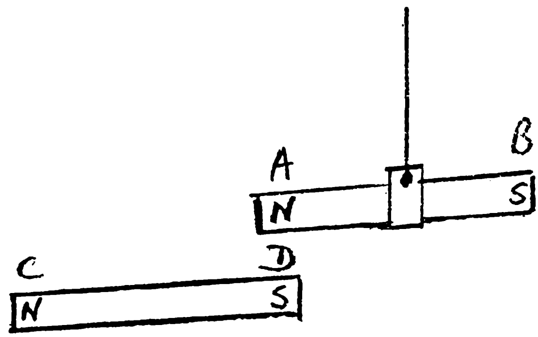
What happens?

Since all these charges, on AB and CD, were produced on the same material in the same way, we must suppose that they are similar or like charges. What general rule about charges do these experiments illustrate?

b. An exactly similar experiment is done with polythene strips EF and GH rubbed with cloth, figure 49 (*b*). These also are 'like' charges. Are the observations different from, or the same as, before, when acetate strips were used?

50 *a.* Still using the apparatus of question 49, we now try bringing up the charged polythene strip GH to the suspended and charged acetate strip AB. What is observed this time? Does it make any difference if the acetate strip is brought up to a suspended charged polythene strip?
b. What general rule do the observations in (*a*) illustrate?
c. What happens when a metal ruler, or piece of wood, or any uncharged object, including the hand itself, is brought up to (*i*) the suspended acetate strip, (*ii*) the suspended polythene strip?

Figure 51



51 You have earlier performed experiments similar to those of question 49 with magnets. See figure 51.

a. Do the magnets and the charged strips give the same or different results? In what way are they different?
b. What sort of compound (acetate–polythene) strips would give the same result as the magnets give?
c. Do you remember what happens when a magnet is cut in half? What, then, is another important difference between magnets and charged strips?

52 The following experiments are done with the small very light spheres that are usually known as 'pith-balls' (even if they are made of plastic material rather than wood pith).

a. A ball is suspended on its nylon thread and a charged acetate strip is brought near. What happens?
b. The ball, untouched by fingers, is rubbed with the acetate strip. The strip is removed and then brought up to the ball again. What happens?
c. A charged polythene strip is brought up to the ball, which is still charged with the acetate kind of charge. What happens?
d. The ball is now charged from the polythene strip and the polythene strip is brought up to it. What happens?
e. The acetate strip is brought near the polythene-charged ball. What happens?
f. State the simple rule (or 'generalization') that covers all the above happenings.

53 We shall now investigate conductors and insulators.

Apparatus: A suspended 'pith-ball', and an acetate or polythene strip, also pieces of material to test – first your own hand, which you will soon show to be a conductor, then things you can hold in the hand, such as nylon thread, cotton, wood, wax, metal, plastic materials, paper, etc.

a. Say in a few sentences how you would carry out this investigation.
b. List a few things that can be classed as 'conductors', and a few that are 'insulators'.

54 *a.* In pith-ball experiments, such as those in questions 52 and 53, it is important for the balls to be supported on an *insulating* thread, and to be coated with a *conducting metallic* layer. Why is this?
b. You investigated conductors and insulators using electrical circuits, containing a battery, in Section 3; see question 29.

What differences are there between what you found when using a current circuit and what you found when using the pith-ball?

c. Last, a difficult question. What reason is there for the difference between what you class as 'conductors' in current circuits and what you class as 'conductors' in pith-ball and charged-strip experiments?

55 We have seen that there are two kinds of charge, 'acetate', and 'polythene'. We can try other materials to see which sort of charge (if any) they have when they are rubbed with cloth or other material.

a. If we hold them in the hand in the usual way, then the only materials we can test are insulators. Why cannot conductors be tested in this way?
b. Even so, we must see that they are as dry as possible. Why?

56 We have two pith-balls, one 'acetate' charged, the other 'polythene' charged. We bring up one of the things we want to test, e.g. a fountain pen rubbed on a coat sleeve.

a. If it attracts the 'acetate' charged ball and repels the 'polythene' charged ball, which sort of charge does it have, 'acetate' or 'polythene'?
b. If it repels the acetate ball and attracts the polythene, which sort?
c. If it attracts both, what then?

(If it repels both you have either discovered a third kind of electricity, or you have made a mistake somewhere!)

57 A foot length of thin aluminium foil, about a centimetre wide, is folded back on itself at the middle, and is then hung on an insulating rod. The foil is then charged by rubbing the top part, where it hangs on the rod, with a charged acetate or polythene strip. What happens, and how do you explain it?

58 A metal disk held on an insulating handle is rubbed by a charged acetate strip. It is then brought near a suspended pith-ball, the ball is attracted to the disk, touches it and is immediately repelled away.

a. How do you explain the effect of attraction followed by repulsion?
b. Why is it that this always happens when the ball is charged from the disk, but rarely or never when the ball is charged from the strip?

59 *Following on from question 58.* Suppose we have the arrangement drawn below. The pith-ball is held between the plates and then released.

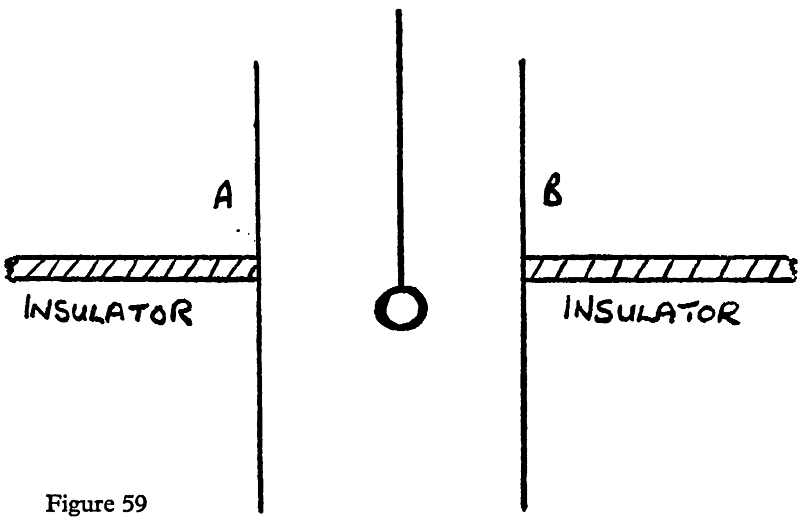


Figure 59

a. Plate A had been charged by rubbing with a charged acetate strip, and B by rubbing with a charged polythene strip. What happens to the pith-ball? Give the reason for your answer.
b. What happens if A is 'acetate-charged' and B is uncharged? Give the reason for your answer.

Note: There are two slightly different answers to (*a*), either of which will be counted correct. A third answer is that the ball cannot make up its mind whether to be attracted by A or by B, and so stays put; this will be counted wrong!

60 We believe that the charges we get on acetate and polythene strips are 'electric' charges just like those from a battery.

a. Describe briefly any experiment you have seen that shows this.
b. How, in that experiment, was it possible to discover that the charge on the acetate strip is the same as that from the red terminal of a battery or generator, while that on the polythene strip is the same as that from the black terminal?
c. Write 'positive' or 'negative' in the spaces below:
'Acetate strip or red terminal of battery or generator is called . . .'
'Polythene strip or black terminal of battery or generator is called . . .'

61 In our earlier work on conduction of electricity in gases we saw some evidence for believing that the hot gases from a flame could conduct electricity. How would you arrange an experiment to discover whether the air and burnt gases immediately above a Bunsen or candle flame are able to cause a charged object to lose its charge?

8 Different kinds of forces*

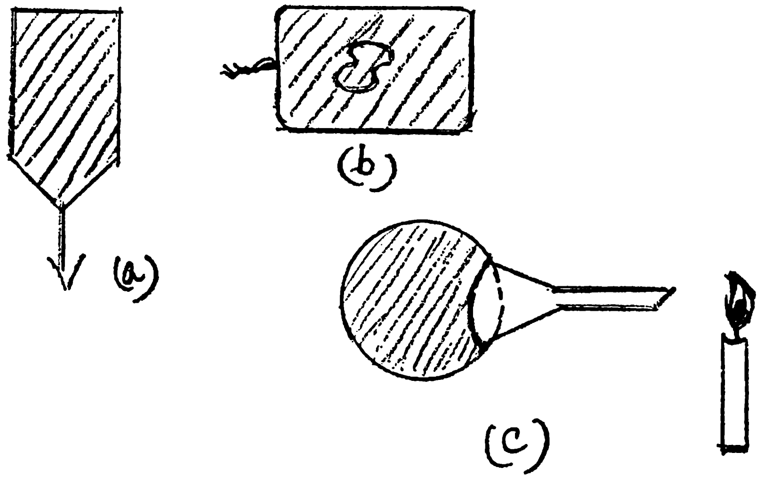


Figure 62

62 *a.* A soap film is contained within a three-sided frame of wire, figure 62 (*a*). The fourth side is a slack piece of cotton which is then kept taut by a second piece of cotton tied at the middle. This latter piece is then released; show what happens by means of a sketch.
b. A soap film is formed on a complete rectangle of wire and a small loop of cotton is dropped on as shown in figure 62 (*b*). The film *inside* the cotton is then broken with a hot needle, or a piece of blackboard chalk. Sketch what happens, and give the reason in not more than two sentences.
c. This time a soap bubble is blown on the end of a small filter funnel, figure 62 (*c*), and the open end of the funnel is held near a candle flame. What happens to the flame and what happens to the bubble? What do these observations tell you?

63 A steel tyre is put on to an iron locomotive wheel in the following manner: the steel tyre is made so that it is a little too small to fit on to the wheel, then it is heated so that it expands and can be

* *Note to teachers:* The teaching about forces in Year II is intended to prepare for the discussion of energy (continued from Year I). Only with a very fast group should this teaching begin to discuss force and motion – that belongs in Years III and IV. So some of the questions in this section are only suitable for a fast group.

knocked on to the wheel, while it is still very hot. Then it cools and grips the wheel very tightly. When this has been done:

a. In what direction(s) are the forces in the steel tyre?
b. In what direction(s) are the forces exerted by the tyre on the spokes of the wheel?
c. *Difficult*. If you can do so without spending more than, say, five minutes in thinking about it, explain, with a diagram and in a sentence or two of writing, how forces in one direction in the tyre have produced forces in quite different directions in the spokes.

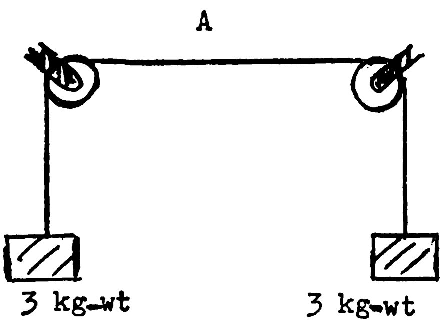


Figure 64(*a*)

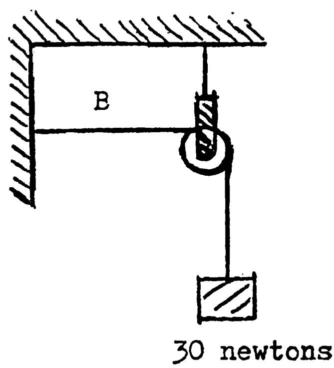


Figure 64(*b*)

64 *a*. Freddie Jones says the force in the string (tension) at A, figure 64 (*a*), is 6 kg-wt; what do you say? What curious thing would happen if Freddie were right?
b. You and Freddie agree that the tension at B, figure 64 (*b*), is – what? By the way, Freddie drew the picture and it's slightly wrong – what's wrong with it?

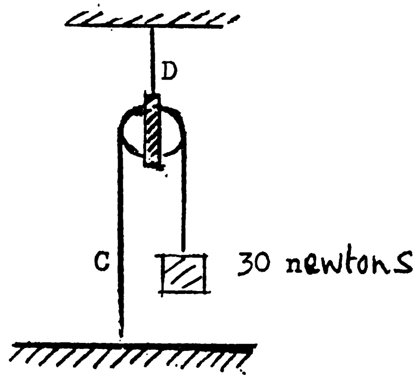


Figure 65(*a*)

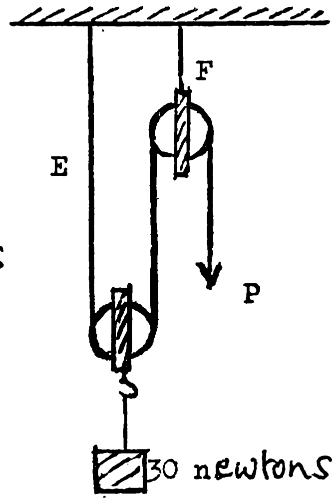


Figure 65(*b*)

65 *a. Difficult.* The pulley in figure 65 (*a*) weighs 4 newtons. What are the tensions at C and at D?
b. Difficult. The pulleys in figure 65 (*b*) each weigh 4 newtons. (*i*) Find the force with which a man must pull on the string at P in order to hold up the 30 newton weight and the pulleys. (Remember that the tension is the same all round the same piece of string.) (*ii*) What is the tension in the small length of string at F?

Figure 66

66 Figure 66 is a simplified diagram of an apparatus for finding the friction between a wooden block and a plank. The plank is pulled steadily to the left while the block is held in place by a spring balance on the right. The frictional force between the block and the plank is then equal to the reading on the spring balance. The block is rectangular and it measures 15 cm × 10 cm × 5 cm. It weighs 500 gm. When the plank is pulled at a slow steady speed, the balance reads 300 grams-weight.

a. The plank is then pulled at twice the previous speed; do you expect (from experiments you have done or seen) the balance reading to be 300 grams weight? Or 600? Or 150? Or what?
b. We again pull the plank with the earlier 'slow steady speed', and this time, an extra 500-gram load has been placed on the block. What do you expect the balance to read now?
c. During these experiments the block had one of its largest faces in contact with the plank. The block is turned so that a smaller face 15 cm $\times$ 5 cm is in contact; what does the balance read?
d. The plank and block are at rest and the balance pointer is at zero. Then the pull on the plank is slowly increased till slipping occurs. Is the balance reading *just before* the block starts to slip 300 grams-weight, or more, or less?

67 As we saw in experiment (*d*) of question 66, there is a difference between the frictional force when two surfaces are about to slip and when they are already slipping. What application does this observation have:

a. to the skidding of car-tyres on a smooth road?
b. in an orchestra? (What scrapes over what in an orchestra?)

68 A small object, which is 'heavier' (denser) than water is held at rest, just under the water in a deep pond and then released.

a. Write one or two sentences describing its motion after you have let go. (If you can, draw a rough graph of downward speed or velocity against distance fallen.)
b. Describe, in your own words, the meaning of 'terminal velocity'.
c. When a falling object reaches its terminal velocity, what is the total of all the upward and downward forces acting on it?

69 *a.* You have completed some experiments on light objects – paper 'trays' with bent-up edges – falling in air. Describe *two* experiments you did which led to useful or interesting conclusions, and say what these conclusions were. (Write about two sentences for each experiment, and one for each conclusion.)
b. What sensible scientific experiments might be carried out with the paper trays using each of the following pieces of apparatus?

(*i*) A lighted cigarette.
(*ii*) Several pennies.
(*iii*) A punch that makes holes in paper.
(*iv*) An electric fan.

70 Try the following experiment. Get a penny. Cut a small disk of stiff paper the same size as the penny. Hold the penny flat between the thumb and fingers of one hand. Hold the paper disk in the same way with the other hand. Let both drop at the same time.

a. Which reaches the floor first? How do you account for the difference?
b. Now put the paper disk on top of the penny and drop both together. What happens?
c. Freddie Jones has done the same experiment, and he says it shows that, if air resistance is removed, paper falls as fast as pennies. The experiment certainly does not disagree with this conclusion, but would you go all the way with him in saying that 'it shows that . . .'? If not, write a sentence or two saying why not. What would be a more satisfactory experiment to show the same thing?

71 *a.* A man with a parachute weighs more than a man without one, yet he falls more slowly. Why?
b. An aircraft dives vertically with its engines off. It reaches a constant speed of 350 mph. What two forces are acting on it when it reaches that terminal velocity? What can you say about these two forces?
c. The aircraft is still diving when the pilot switches on the engines (a 'power dive'). What happens now? Assume the plane does not hit the ground or break in pieces. Why is it likely to break in pieces under this treatment?

72 *Quotation:* 'An earwig, a cat, a man, and an elephant all fall over a high cliff. The earwig walks away unharmed, the cat breaks a leg, the man is killed, and the elephant splashes.' Why is there this difference?

73 *a.* What is another, shorter name for 'pull of the Earth'? Name three units in which it can be measured.
b. An object is weighed on a spring-balance and is found to weigh 6·2 newtons. Would it show the same reading, or more, or less, if object and spring-balance are on the Moon? On Jupiter?

c. A catch question. The same object is again weighed on Earth, this time on a beam balance. It is balanced by masses whose total weight is 6·2 newtons. It is then weighed on the beam balance on the Moon and on Jupiter. Is the result the same as in (*b*)? If not, say why.

74 You are given a spring-balance (with a pan attached) and a scale which is completely blank and unmarked. You are also given a single load weighing exactly 1 newton and a bottle full of small lead shot. How would you proceed to mark the scale in newtons by putting marks at 0, 1, 2, 3, 4 and 5 newtons,

a. If the spring-balance follows Hooke's law, that is, the stretch increases in direct proportion to the load on the pan?
b. If the spring-balance does *not* follow Hooke's law?

75 If you can find a copy, read H. G. Wells's short story, 'The Strange Case of Mr Pyecroft'. Then say why a better knowledge of physics would have made Mr Pyecroft more cautious in using the Indian formula.

9 Energy transfer. Position energy. Heat.*

76 Here are some more examples of energy transfer like those in Year I.

You are asked to copy out (*b*) to (*g*) below, completing them in the same way as (*a*). (*Note:* Energy from man or animals, derived from food, is chemical energy.)

a. Child spins top, top hums and finally comes to rest.

Energy changes: $\text{chemical} \rightarrow \text{kinetic energy} \begin{array}{l} \nearrow \text{heat} \\ \searrow \text{sound} \nearrow \text{heat} \end{array}$

b. Car generator charges accumulator, which, later on, lights head-lamps.
Energy changes: . . .

c. Wind turns 'windmill' sails of a windpump, windpump raises water out of ditch into a river at a higher level.
Energy changes: . . .

d. Water in high reservoir runs down large pipes and turns blades of turbine wheel at the bottom; turbine drives electric generator; generator supplies current to electric fire in your room.
Energy changes: . . .

e. Bullet placed in rifle, trigger pulled, hot gases formed in gun-barrel, bullet shot out, hits wall.
Energy changes: . . .

f. Nuclear reactor makes high-pressure steam, which turns a steam turbine, which drives a generator, which makes electricity.
Energy changes: . . .

g. Radium atom emits fast alpha-particle which hits a fluorescent screen and makes a faint 'splash' of light.
Energy changes: . . .

* Many of the problems of Year I on 'Energy and work' are suitable revision material. These problems are reprinted as an appendix at the end of this book.

77 A brick weighing 5 lb is lying on the ground. A man picks it up and raises it to 6 feet above the ground. He then allows it to fall.

a. How much energy (ft.-lb) does the man transfer in lifting the brick?
b. What is the increase of uphill energy of the brick when it is lifted 6 feet above the ground?
c. What is its motion energy just before it hits the ground?
d. What happens to this energy after it hits the ground?

78 Suppose, in the last question, that the brick, instead of hitting the ground, had fallen into a hole 1 foot deep.

a. What is its motion energy just before it hits the bottom of the hole?
b. How do you account for the fact that it seems to have acquired more motion energy than is equivalent to the work the man did in lifting it?

79 *Scientific units.* Suppose that in questions 77 and 78 the brick has a weight equal to 25 newtons and that it is raised 1·6 metres. Also (question 78) suppose that the hole is 0·4 metre deep. Now work out the answers (which will be in *joules*) to these questions:

a. How much work does the man do in lifting the brick?
b. What is its kinetic energy just before it hits the bottom of the hole?

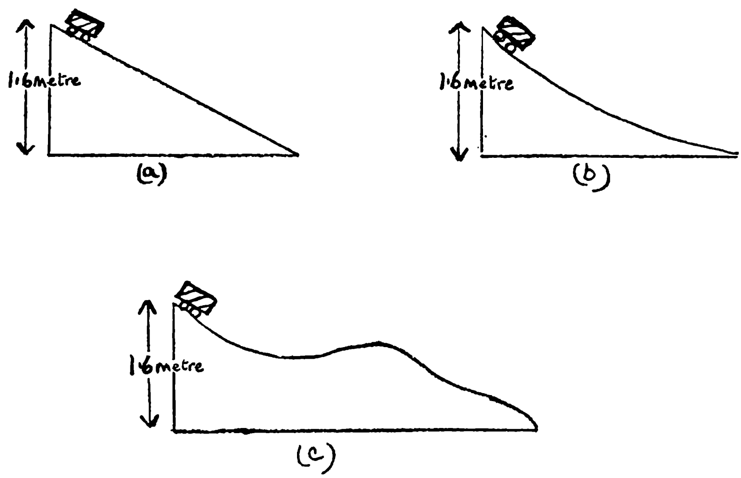


Figure 80

80 A small cart, whose weight is 6 lb, runs down a straight sloping hill, figure 80 (*a*), or curved hill, figure 80 (*b*), or a 'switchback', figure 80 (*c*). What is its motion energy when it reaches the bottom, in (*a*)? in (*b*)? in (*c*)? (Friction is supposed to be negligible in each case.) What can we say about the velocity of the trolley at the bottom of each hill?

81 Figure 81 shows a brick put on top of a piston that encloses air in a cylinder (like a bicycle pump – with the end closed). The piston descends, oscillates up and down two or three times, and comes to rest 4 inches lower down than it was before. The gas is compressed when the piston moves down. The brick and piston together weigh 7 lb.

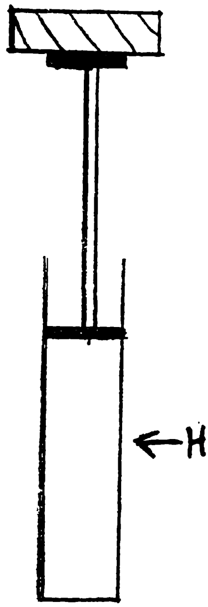


Figure 81

a. How much uphill energy was lost as the piston fell 4 inches?
b. Why did the piston fall, at first, more than 4 inches?
c. Why did it come up again?
d. Why did it finally come to rest?
e. What could have happened if there had been a very small hole in the piston?
f. Suppose the piston was airtight, but there was a very small hole at the point H in the diagram. Which of the following statements is correct? Give the reason for your answer.

(*i*) The piston stops at H.
(*ii*) The piston falls to the bottom of the pump.
(*iii*) The piston stops above H.
(*iv*) The piston stops below H.

82 Remember that we have explained gas pressure by saying that it may be caused by the bombardment of the molecules of the gas. A bicycle pump is held with the handle at the top, *and the lower end is open.* The handle (and piston) is pushed down.

a. What change in the motion of the air molecules in the pump occurs as the piston moves down?

b. How does this change take place? That is, how does it happen?
c. What happens to the air?

Now think of the pump *with the lower end tightly closed.* Again the piston is pushed down; let us say, half-way along the pump barrel.

d. Does the change you mentioned in *a* still take place? If you say *it does not*, give the reason for your answer. If you say *it does* then answer (*e*).
e. The air cannot now get out of the pump. Yet the piston pushed the molecules downwards (you have agreed). What has happened to this downward motion of the molecules? And what can you say about the temperature of the air in the pump?

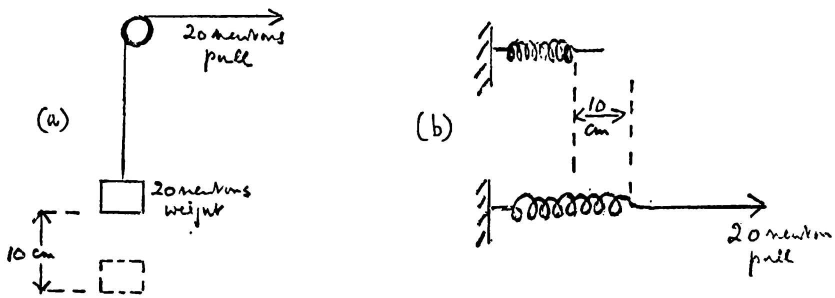


Figure 83

83 *a*. A man lifts a weight of 20 newtons through a height 10 cm (0·1 metre), figure 83 (*a*). How much uphill energy is thereby given to the weight?
b. A man extends a spring through a distance of 10 cm (0·1 metre), figure 83 (*b*). The force he finally needs to hold the spring in position is 20 newtons. All the time he is stretching he uses no more force than is necessary to stretch it, that is, the first bit of stretch is accomplished with a force that is practically zero, and only at the end does he have to exert 20 newtons. Why, in doing this, does he store less spring energy in the spring than was stored in the weight (question (*a*)) when it was lifted 10 cm?
c. Make a guess at the actual amount of energy likely to be stored in the spring in question (*b*). (The obvious answer is the correct answer, provided that the spring behaves elastically throughout the 10 cm stretch.)

84 *a.* Look back at question 83. In (*a*), suppose we let the weight fall back to the floor. In (*b*), let the spring relax, oscillate, and come to rest. What is the final form of the energy?
b. Give two other examples of energy charges in which the same final energy form is reached.

85 Your answers to question 84 show that energy very often gets converted into heat. All the same, it *is* possible to convert heat into other forms of energy, or at any rate, to convert some of it. The essential thing in any machine that converts heat into some other form is that there *must* be a difference of temperature that the machine can use.

a. Give the name of some form of 'heat conversion machine' and say how the necessary temperature is obtained.

Conversely, if we have a number of things all at the same temperature (all at room temperature for example) we cannot make and continuously maintain a difference of temperature without supplying energy from outside.

b. Very likely you have in your home, or have seen somewhere, a machine which, starting with everything at room temperature, makes some things colder and other things hotter. What is it called? And, in the one you are thinking about, in what form does it get its supply of outside energy?

10 Measurement of heat

86 *a.* How have you found the heat produced in one minute by an electric heater?
b. The heat unit you used is the 'kilocalorie'. Why 'kilo'? What does 'kilo' mean? What is a kilometre?
c. Would you expect the result you obtained by the experiment in *a* to be smaller, or larger, or equal to the true value? Give a reason for your answer.

(Assume that your measuring instruments – clock, thermometer, balance – are not at fault.)

87 A boy obtains two results from two experiments to determine the heat given out per minute by an electric heater. In the first experiment the temperature of about 2 kilograms of water rose by about 10° C. In the second experiment, the heater was switched on for the same number of minutes in about half the quantity of water, and produced about twice the temperature rise. The boy uses a thermometer marked in whole degrees, and he believes he can estimate temperatures with it to the nearest $\frac{1}{10}$ of a degree.

a. Why is the first experiment, with the larger amount of water heated through a smaller temperature rise, likely to give a more accurate result than the second?
b. The boy then says: 'I shall get a still more accurate result by heating 10 kilograms of water through about 2° C – or even 20 kilograms through 1° C.' Why is this not a good idea?

88 *a.* How much heat (kilocalories) is required to warm up 0·5 kg of water from 15° to 25° C?
b. 3·6 kilocalories are required to raise 0·5 kg of brine (saturated salt solution) from 15° to 25° C. What value for the specific heat of brine may be calculated from these figures?
c. What does 'specific' mean? – that is, why use 'specific' when talking about (for example), 'The specific heat of aluminium'?

89 Suppose the heat required to warm 1 kg. of water through 1° C was only one-tenth of what it actually is; that is, suppose the specific heat of water was one-tenth of its actual value.

a. What difference do you think this would make to the climate of an oceanic island?

b. What difference would it make to the pleasure (if so it be) of a long and lingering hot bath?

90 You are given a thermometer, a balance, a candle, a tripod, and a tin of suitable size:

a. How would you attempt to find the heat given out by the candle per minute?
b. Why is this experiment likely to give too low a value for the kilocalories per minute from the flame?

91 You have measured heat, supplied to solids and liquids, by means of a balance and a thermometer.

a. A thermometer does not, by itself, measure heat energy. What name is given to the quantity it does measure?
b. Outline briefly an experiment in which different quantities of heat produce the same change of reading on the thermometer, and another in which the same quantity of heat produces different changes of reading on the thermometer.
c. How do you calculate heat (kilocalories) from the readings of the balance and the thermometer:

(*i*) if the substance to which you supply heat is water;
(*ii*) if it is something else, not water.

11 Effects produced by heat

92 One effect of heat is given under (*a*) below, together with a particular example of that effect. Another effect is given under (*b*): give one example of this. Then list two more effects, together with examples, under (*c*) and (*d*).

a. Heat makes some chemical reactions take place more quickly, e.g. coal heated sufficiently in air, catches fire.
b. heat causes expansion: e.g. . . .
c. . . .
d. . . .

Note: 1: (*a*) differs from the other examples you have probably given in that it is *self-sustaining*, that is, some of the coal, in burning can produce sufficient heat to cause the rest to go on burning. Of course the heat may be lost too rapidly for the burning to be sustained, e.g. if it is a small piece of wet coal, or there is a powerful wind – think of the difficulties of lighting fires under such conditions.

Note: 2: one effect of heat is so simple and obvious that you probably did not think of it – heat produces rise of temperature. This is what the questions in Section 10 were about.

93 Describe and explain briefly one useful application of the expansion with increasing temperature of: (*a*) a solid; (*b*) a liquid. Also, (*c*) describe briefly one case of expansion with temperature being a nuisance, and explain how the effects of this expansion may be reduced or eliminated.

94 Look at the left-hand diagram of figure 95, which shows a 'bi-metallic strip' of iron and copper firmly fastened together. For the same temperature rise, copper expands $1\frac{1}{2}$ times as much as iron.

a. What happens when this strip gets warmer; does it touch C or D? Give the reason for your answer.
b. What happens when the strip is cooled?

95 You are given two electric bells X and Y and a battery that will work them (one at a time), also connecting wires, and the apparatus shown on the left of figure 95. This apparatus consists of a bi-metallic iron–copper strip, fixed at AB and with the other end free. Electrical leads are taken from the fixed end AB, and from the two con-

tacts at C and D. The idea is to put the bi-metallic apparatus in an enclosure which is supposed to be kept at constant temperature. If the enclosure gets too cold, then bell X is to ring, if the enclosure gets too warm, then bell Y rings.

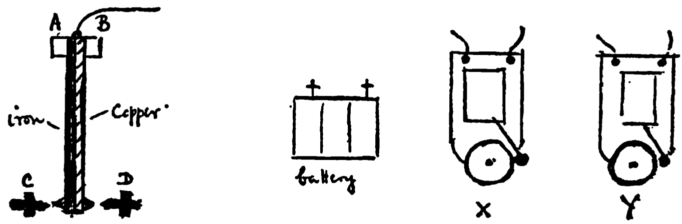


Figure 95

Draw a circuit showing suitable connections, and explain how the whole arrangement works. *Note:* Copper expands $1\frac{1}{2}$ times as much as iron for the same temperature rise.

96 Why are the melting point of ice and the boiling point of water good temperatures to take for the 'fixed points' (0° and 100° C) of a thermometer scale? What numbers represent these points on the Fahrenheit scale?

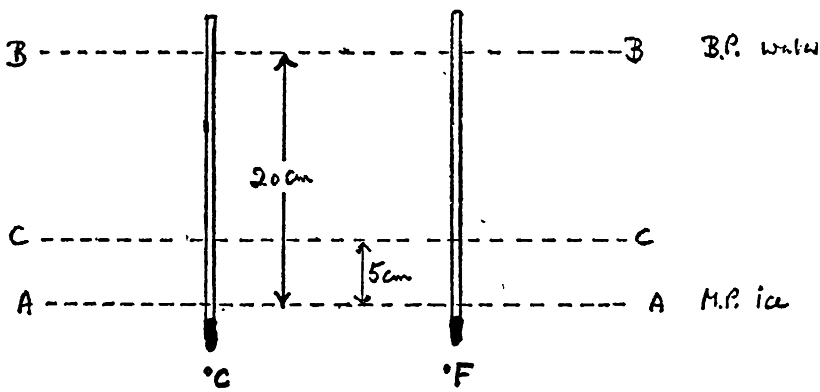


Figure 97

97 *No formula is needed to be used in this problem, common-sense and arithmetic are enough.*

Two identical thermometers are to be marked, one with a Centigrade scale and the other with a Fahrenheit scale. On each thermometer the distance between the ice point and the boiling-point is 20 cm (AA to BB in figure 97).

CC marks another point on the two thermometers 5 cm above AA.

a. What temperature should be marked for A, B and C on the Centigrade thermometer?
b. What temperature should be marked for A, B and C on the Fahrenheit thermometer?
c. How far above A would the 80° C mark come?
d. How far above A would the 144° F mark come?

98 Galileo made a thermometer like that in figure 98. A flask is fitted with a tube and is inverted so that the end of the tube is under water. The amount of air in the flask is adjusted so that the water level comes to some convenient point in the tube.

a. How does the arrangement work as a thermometer, i.e. why does it give different readings for different temperatures?
b. This is not a good form of thermometer. It might give quite different readings on days when the temperature was in fact the same. Explain why.

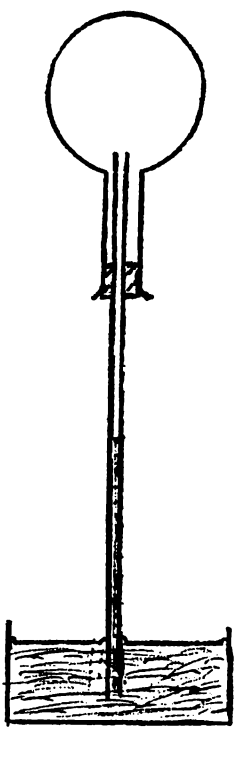


Figure 98

99 A beaker of cold tap-water is placed on a tripod and gauze, and is gently heated with a Bunsen till the water boils; it is then boiled for a further 5 minutes. A thermometer is immersed in the water throughout, and the water is gently stirred. Explain each of the following observations:

a. First the beaker gets cloudy *outside*. The water is still cold.
b. The water gets a little warmer and the cloudiness clears.
c. Later small bubbles are seen in the water. They rise to the surface. The temperature is still well below 100° C, but a mist or steam is seen above the surface.
d. Large bubbles rising rapidly to the surface are seen, and plenty of steam is coming off.

100 *Continuing with 99 (d).* During the 5 minutes the water is boiling the reading of the thermometer remains the same. How do you explain the fact that the Bunsen is still supplying heat all this time, yet nothing is getting hotter?

101 *a.* It takes 540 kilocalories of heat to convert 1 kg of water at 100° C into steam. How many kilograms of water could be raised from freezing point to boiling point by this amount of heat?
b. Suppose the heat required to boil away 1 kg of water were 5·4 kilocalories instead of 540; what disadvantages would then afflict the cook in her kitchen?

102 *a.* On a windy beach a wet bathing costume is much colder to wear than a dry one. Why?
b. You get hot, perspire, and then sit in a draught. You are very likely to catch a chill. Why?

103 *a.* Why is it that 25 gm of ice at 0° C is much more effective in cooling lemonade on a hot day, than is 25 gm of water also at 0° C?
b. How would you know, simply by putting a piece of ice into water, that water expands on freezing?
c. After freezing weather a thaw comes, and pipes in exposed places are then found to have burst. Therefore, a thaw produces burst pipes. Is this reasoning correct? Explain.

104 *a.* The lid is rammed down hard on an empty syrup tin (which means, of course, a tin full of air). The tin is placed on a gas burner. In a few seconds the lid blows off. Why?
b. A little water, nearly at boiling point, is poured into a vacuum flask and the cork is pushed on. The flask is gently shaken and the cork blows out. Why?
c. Freddie Jones took a thin-walled can which could be closed by a cork, and put a little water in it. Then he placed the can on a tripod and heated it till the water boiled. He kept the water boiling for a minute, then he removed the Bunsen and at the same time pushed in the cork. The can was allowed to stand; after some minutes, he said, it went 'gnab'. Why 'gnab' rather than 'bang'? And why did it go 'gnab'?

Note: The object of question 105 is to give you some idea of the volume changes taking place when the temperatures of solids, liquids and gases are raised, and when liquids freeze and boil. Use commonsense rather than books in writing down the answers.

105 Here are four numbers, all expressing volumes:

1·007 c.c.; 1·1 c.c.; 1·4 c.c.; 1600 c.c.

Here are five questions, and one of the numbers above is the best answer to each question (one of the numbers must be used *twice*).

a. 1 c.c. of air heated from 0° to 100° becomes . . .?
b. 1 c.c. of water at 100° C heated to steam at 100° C becomes . . .?
c. 1 c.c. of alcohol heated from 0° to 100° C becomes . . .?
d. 1 c.c. of water at 0° C cooled to ice at 0° C becomes . . .?
e. 1 c.c. of aluminium at 0° C heated to 100° C becomes . . .?

12 Conduction and convection

106 Lay your hand on a number of different objects in a cool room, or out-of-doors but not in direct sunshine. The objects will all be at nearly the same temperature, which is considerably below body temperature.

Although they are at the same temperature, some feel cold and some, by contrast, feel pleasantly warm. Choose about a dozen different surfaces – metals of various kinds, wood, paper, etc. Do not touch any one of them more than a second or so, or it may be appreciably warmed by your hand. Make a list of the materials under two headings:

(*i*) materials that feel cold to the touch.
(*ii*) materials that feel warm to the touch.

If you think you ought to, you could also have a third 'in-between' category of materials.

107 The substances you felt with your hand in question 106 may have included copper (in category (*i*)) and plain unvarnished, unpainted, unpolished wood (in category (*ii*)). Now try the following simple experiment if you can – if not, well you can guess what happens. You need copper wire about the same thickness as a match-stick (16 S.W.G. will do). Cut off a piece the same length as the match. Strike the match and hold the copper with one end fully immersed in the flame. Keep match-stick and copper horizontal. The match burns down, but which do you drop first, the match-stick or the copper wire? We conclude (fill in the missing words):

a. 'Copper is a . . . . of heat than wood.'
We can now use this conclusion to 'explain' our observations in question 106.
b. The copper-like materials in category *i* were at the same temperature as the wood-like materials in category *ii*, yet the first felt warm and the second felt cold. How can you explain this?

Note: that one common meaning of the word 'explain' in physics is to link together quite different observations and to ascribe them to a similar cause, in this case the different conductivities for heat of different materials.

108 Suppose the experiment of question 106 were done in hot sunshine, then the categories would be reversed: copper and other metals would 'feel hot'; wood and cloth and so on would 'feel cold'. How do you explain this?

109 Give a diagram for, and describe in a few sentences, some method of comparing the 'abilities to conduct heat' of two or more different metals. (A shorter way of writing 'ability to conduct heat' is 'conductivity'.)

110 *a.* Of the metals *iron*, *aluminium*, *lead*, which do you think is the best conductor and which the worst? What can you say in support of your answers if someone says they are wrong?
b. In order to attain the smallest possible loss of heat by conduction, would it be best to surround an object by rubber, or cotton-wool, or asbestos, or a vacuum? Give a reason for your answer.
c. Does the Earth receive any heat from the Sun by conduction? Give a good reason for your answer in one or two sentences.

111 An iron poker is put in a fire and a similarly shaped piece of copper is placed beside it.

a. After a few minutes the end of the iron poker which is in the fire is red-hot, but the copper is still dull – why?
b. Which bar can you take out of the fire with your hand, and which will you have to take out with the tongs, or at least, with the help of a handkerchief? Write a sentence or two of explanation.

Note: this experiment could also be performed with thick pieces of iron and copper wire held with one end of each in a Bunsen flame.

112 We can explain how conduction of heat takes place if we make three assumptions about atoms in solids:

1. The atoms have fixed positions and cannot move from one place to another, but they can oscillate and 'jig-about' without moving far.
2. The higher the temperature, the greater the agitation of the atoms.
3. Atoms push and pull each other, so motion of atoms can be conveyed from one atom to the next.

a. Supposing this picture of atoms in motion is true, describe how heat travels from the hot end of a poker to the cooler end.

b. Figure 112 shows a number of balls joined by light springs. Why has this been drawn? What has it got to do with your answer in (*a*)?

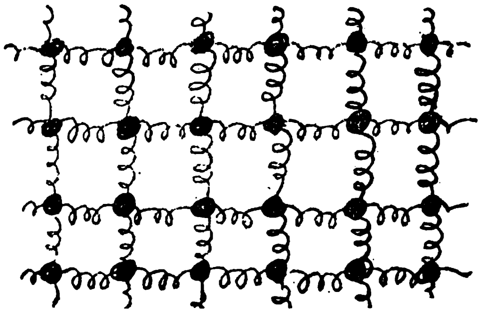


Figure 112

113 *a*. You put a piece of ice in a test-tube and wedge a piece of wire gauze over it to stop it floating. The tube is then filled nearly full of water and you hold the top part of the tube in a Bunsen flame. What do you notice about the water and the ice, and what do you conclude about the heat conductivity of water?
b. You fill another tube with water, like the first, and a small piece of ice is dropped in. The ice floats on the top. Now the tube is heated at the bottom. What do you notice this time (in contrast to (*a*)), and what conclusion can you draw?

114 A boiling-tube, i.e. a wide test-tube about 1″ diameter, is taken and a little aluminium powder is dropped in (the powder used for making aluminium paint). The tube is filled with cold water to which one or two drops of detergent have been added; a cork is put in the top; then it is shaken and the liquid and powder allowed to come to rest. The result is not a solution; it is a suspension of aluminium powder in water. (Without the detergent the powder cakes together, or else floats on top.) The experiment is simply to put your thumb against the side of the tube, but first make sure your thumb is nice and warm!

a. What do you expect to see happening? Or, if you can do the experiment, what did you see happening in fact?
b. How do you explain what happened?

Note: This is like the 'dye' (potassium permanganate) experiment, but better because it is simpler and the same liquid can be used con-

tinuously instead of only once. Benzene is even better than water, and no detergent is needed – also, if dry aluminium powder is unobtainable you can add aluminium paint to benzene, which won't do with water of course. But do *not* have benzene and lighted bunsens on the bench at the same time!

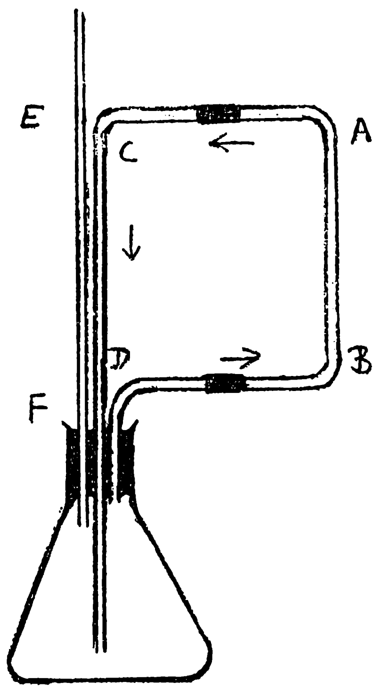


Figure 115

115 Figure 115 shows a model of a hot-water system. Bent glass tubing forms the water circuit. A few crystals of potassium permanganate are dropped in to colour the water – if these are first covered with grease or vaseline they will not start to dissolve until the water is warm.

When the flask is heated, the water starts to circulate.

a. Explain why the water circulates.
b. The water will probably circulate in the direction BACD, but to make certain it is as well to warm gently the side BA. What would be likely to happen if you warmed DC?
c. What is the purpose of tube FE? (A similar tube is fitted in a domestic hot-water supply system.)

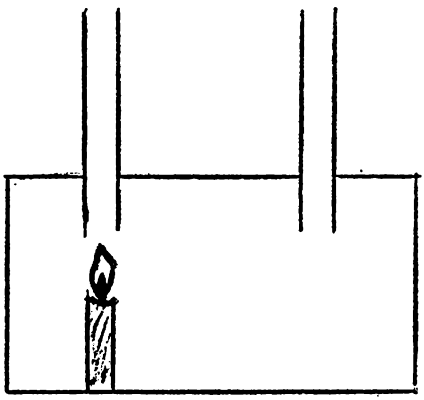


Figure 116

116 A large cardboard box (figure 116) has two tubes fitted into the lid. If one side can be wholly or partly replaced by glass, so much the better. A candle is placed under one 'chimney'. The candle burns brightly.

a. How is the air circulating through the box, and why is it circulating in that way?
b. How would you demonstrate the circulation?
c. Briefly describe some other way of showing convection currents in air.

117 *a*. Air is an even worse conductor of heat than wood, yet a hot tank packed round with loose sawdust retains its heat much better than the same tank in air. Why is this?
b. *Following from* (*a*). Why do clothes keep us warm? Why is wool warmer than cotton when worn as clothing material? Why are two layers of thinner materials better than a single layer of twice the thickness? Birds 'fluff-up' their feathers in cold weather; why does this keep them warmer?

118 *a*. What part is played in the cooling of an automobile engine by (*i*) convection of water, (*ii*) convection of air? Why could both these forms of convection be described as 'forced convection'?

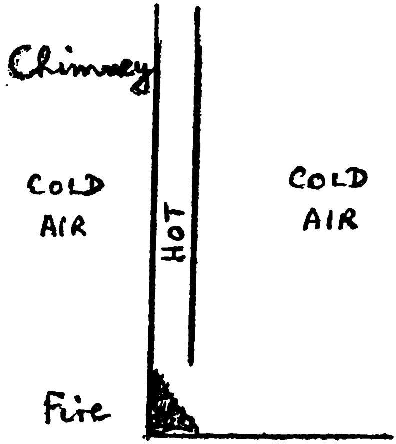


Figure 119

119 With the aid of a diagram similar to figure 119 explain why a tall chimney helps a fire to burn, and why a fire creates a draught in the room where it is burning. Explain also why a fire may be 'sulky' and difficult to get going when first lit, possibly with some smoke coming into the room.

13 Radiation

120 *a.* Without the warmth of the Sun the Earth would soon become an entirely frozen planet. Why can we be sure that no heat from the sun reaches us by conduction or convection?
b. Hold your hand close to an electric-light bulb without touching it, switch on for about one second, so that you feel the warmth, then switch off. Feel the bulb. The glass is cold. We can be sure that no heat has reached the hand by conduction or convection – why can we be sure of this?
c. The name 'radiation' is given to the process in consequence of which the sensation of warmth was perceived in (*a*) and (*b*). Remember that heat is energy in the form of molecular motion – why then can we be sure that 'radiation' is not a process by which heat itself is transferred?

Note: We deduce therefore that what comes to us from the Sun, or from the electric-lamp filament, is not itself heat, but is another form of energy which we call 'radiation energy'. Hot bodies give out radiation energy. Bodies that absorb radiation become heated in consequence.

121 *a.* Describe an experiment to show that radiation may be associated with light, and that it seems to travel in straight lines (like light) and to be cut off by obstacles. Suggested apparatus: an electric heater, and an asbestos screen with a hole in it. As detector of radiant energy: the skin of the back of your hand, or your cheek.
b. Describe a second experiment with similar apparatus to show that radiation energy of the same kind need *not* be associated with light at all, but can come from a source which is invisible in the dark.

(What is a suitable source for this experiment? One suggestion is 'an electric iron'.)

Note: From these experiments we can arrive at a simple (but bold) working hypothesis, namely that light (i.e. something we see without eyes) is one form of radiation (which we feel with our skin); but also that light is *not* the only kind of radiation.

122 Let us consider radiation which is *not* light, i.e. the part that is invisible to the eye. A glass prism 'spreads out' sunlight or light from a lamp into a 'spectrum' of colours: perhaps here we shall find the 'invisible light' which is also radiation.

Describe an experiment you have seen demonstrated in which the spectrum beyond the red and beyond the violet is investigated. What conclusion is drawn from this experiment?

What is meant by 'infra-red', 'ultra-violet'? What part of the radiation from the sun or from a lamp, infra-red, visible or ultra-violet, seems to carry the greatest amount of energy?

Note: This is the same as asking, 'What is there most of, infra-red, visible, or ultra-violet?'

123 A cold object – anything will do, but let us say a penny – is placed near an electric fire – or any other type of fire – and begins to get warm. After a time, although it is still much colder than the fire, it reaches a maximum temperature and stays at that temperature so long as the fire is switched on.

a. What can you say about the heat gained by the penny from the fire, and the heat lost by the penny to its surroundings, under the state of steady temperature described above?
b. What about the heat gained by the penny and the heat it loses to its surroundings while it was warming up before reaching a steady temperature?
c. The fire is switched off, what about heat gained and heat lost now?
d. Back to the steady state of (*a*): the penny is moved nearer to the fire, what now?
e. Last, and more difficult, question. The fire has been switched off for some time, the room is cold and the penny is cold. Is the penny losing any heat? Is it gaining any heat? What do you think?

Note: As a help to answering (*e*) consider the following: suppose the room gets just a little colder than it was, and the penny, for the moment, is at the old temperature, and is a little warmer than the room. What happens? The penny starts to lose heat. But how did the penny *know* the room had got colder and that it ought to start to lose heat? Isn't there a more reasonable explanation?

124 After answering 123, you should have no difficulty with this question, parts (*a*) and (*b*) at any rate.

a. The Earth constantly receives radiation energy from the Sun, and when this energy is absorbed, the Earth is warmed. This goes

on all the time; why doesn't the Earth get as hot as the Sun is?
b. Why is the planet Mercury hotter than the Earth, and the planet Jupiter colder?
c. Our nights are colder than our days, but the difference is nothing like so big as it is on the Moon. On the Moon the day temperature is much greater than it is even at the tropical part of the Earth's surface. The night temperature is much lower than at the poles of the Earth. Can you suggest a reason for this difference between the Earth and the Moon?
d. Why is there a danger of frost on a clear cloudless night, but not on a cloudy night with an overcast sky?

125 One of two similar tin cans is blackened in a smoky Bunsen flame, the other is polished. Equal quantities of cold water are put in each, also a thermometer. A radiator element from a bowl-type electric fire is placed close to them, and equidistant from them (figure 125).

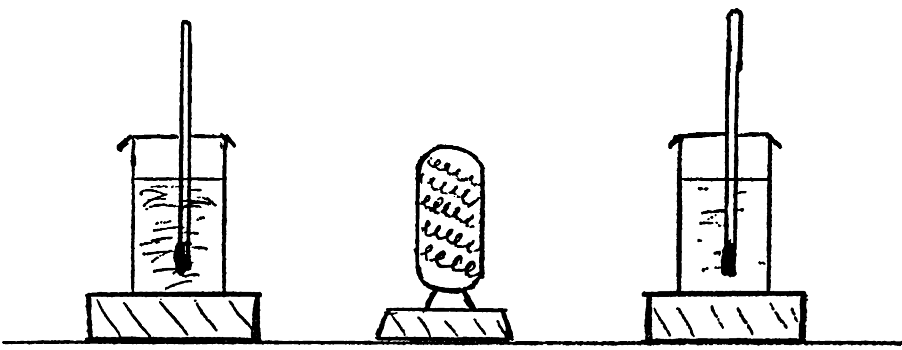


Figure 125

(Alternatively, they can be put outside in strong sunlight.)

a. Which tin shows the more rapid rise of temperature?
b. Describe another experiment to show the same thing happening.

126 The tin cans of question 125 are filled with water near to boiling and are allowed to cool (not near a fire). Which can falls in temperature more rapidly? Describe another experiment to show the same thing.

127 *a.* Is radiation transmitted through glass, or is it absorbed? (This question cannot be answered by a simple 'yes' or 'no'; at least two sentences are required.)

b. On a hot day a saloon car is left in the sunlight with all windows closed. When the driver returns, he finds the inside of the car is considerably warmer than the air outside. There is nothing wrong with the car – why has this happened?
c. Mention a practical application of the observation in (*b*).

128 Four processes by which a hot liquid (e.g. hot coffee) can lose heat are conduction, convection, radiation and evaporation.

a. Find out about the inside of a thermos (vacuum) flask, and explain how heat losses by each of the above four processes are kept down to a minimum.
b. Aunt Agatha says it is silly to take ice-cream for a picnic in a vacuum jar because everyone knows that these are specially made to keep things hot. What do you say, and how do you justify your reply?

129 Explain the following:

a. In sunshine, dirty snow melts more quickly than clean snow.
b. You sit in sunshine that has passed through a clear glass window and you soon feel very warm. But glass is also useful as a fire-screen, to screen you from the radiation energy from a fire.

14 Questions for discussion on heat transfer*

130 By what means does energy travel to you when you are warmed by:

(*1*) The Sun; (*2*) a hot bath; (*3*) an electric bowl fire; (*4*) a gas fire; (*5*) a hot water central-heating radiator nearby; (*6*) a hot-water bottle warming your feet (in contact); (*7*) hot food burning your mouth?

131 A cake is baked in an oven. How does the heat which arrives at the surface of the cake travel to it? Answer this for several different kinds of stove. How does the heat that cooks the inner regions of the cake get to them?

132 In the experiment that you did with aluminium leaf on the back of your hand you felt very little warming when your hand was coated with bright leaf and held near the glowing heater. The explanation of that *might be* that aluminium leaf is a very poor conductor of heat, so that the heating never got through to your skin underneath. What evidence can you quote, from your own observations, for or against that? What does aluminium leaf do to green light or red light, or any kind of light? What do you think it probably did to the radiation that came to it from the glowing heater?

133 In your experiment with a very hot copper sheet, which surface gave out more radiation to your hand, the bright one or the black one? Which teapot would you expect to cool faster – a well-polished silver one or one that had been allowed to tarnish and grow grey?

134 Suppose you lived in a room without any fireplace and without any radiator or hot pipes to warm you except a steam pipe that ran through your room from a boiler somewhere else to some other part of the building to provide steam there. And suppose that the steam pipe was properly protected by a wrapping of asbestos with a cover of bright chromium-plated metal outside that. All you have is a bright chromium-plated pipe going through your room. What could you do, without cutting a hole in the steam pipe, to get more warmth into your room? Suggest several things if you can.

* Some of these are intended to provide useful discussion rather than to ask for a clear 'right answer'.

135 Two families A and B each build a house with a flat roof. A covers the flat roof with black paint. B covers the flat roof with a very bright, smooth, chromium-plated metal sheet. Except for the different roofs, the two houses are just alike. Suppose at the beginning of a cold, clear night both houses are at the same temperature inside. Which house will cool faster during the night? What experiment have you done or seen that illustrates that? Now, suppose that the two houses are at the same temperature at the beginning of a very hot, sunny day. Which house will warm up faster? What experiment have you done or seen that illustrates that?

136 You have seen in experiments that a surface which is good at taking radiation and turning it to heat, such as a black, sooty surface, is also good at giving out radiation; and a surface that does not take in radiation but reflects it, as a bright aluminium surface does, is also bad at giving out radiation. 'Good absorbers are good radiators, and bad absorbers are bad radiators'.

(*a*) If radiation from a glowing electric fire arrives at a sheet of glass, what does the glass do with most of the radiation?
(*b*) Would you expect glass to be a good radiator or a poor one, when it is very hot?
(*c*) What happens when some green light (which is one particular form of radiation, which happens to be in the region of the spectrum where your eyes can detect it) falls on a sheet of glass?
(*d*) Is the glass a good absorber (stopper) of that particular kind of radiation, or a poor one?
(*e*) How do you know?
(*f*) Would you expect a sheet of glass, heated very hot, to be a good radiator of green light, or a bad one?

Appendix Year I questions on energy and work

137 Here is a list of ten 'jobs' done by living and non-living things. Which of these is a 'fuel-using' job, and which requires no fuel?

a. A man hoisting a sack of potatoes off the ground on to his back.
b. Pillars holding up a roof.
c. Air molecules in motion in the room where you are sitting.
d. A piston moving in and compressing air.
e. A man winding a clock spring.
f. A clamp tightly holding a piece of wood.
g. A refrigerator keeping things cold on a hot day.
h. Water keeping a boat afloat.
i. A bus moving along a horizontal road on a windy day.
j. A man or a computer doing sums.

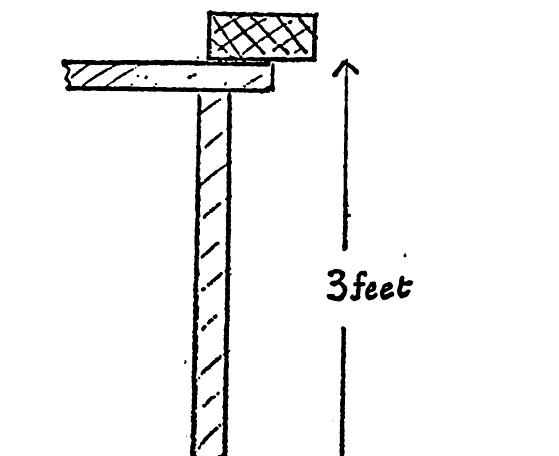


Figure 138

138 A 5-lb brick (figure 138) rests on the edge of a table 3 feet above floor-level. Because it is in this position it can do a job as it falls to the floor: we say it possesses energy-due-to-position, or more simply, position-energy, or 'uphill-energy'.

a. Could the brick do a bigger job if it were resting on the top of a 6-ft-high bookcase? How much bigger? What would you say about its uphill-energy?

b. Suppose there were a hole in the floor, exactly beneath the brick which is 6 ft up, as in (*a*), and that the room beneath was 9 ft high. How would the energy which the brick loses in falling to the floor of the room beneath compare with the uphill-energy it had on the table in figure 138?
c. Do you think you could increase the uphill-energy of the brick by cutting a hole in the floor? Answer 'yes' or 'no' and give the reason for your answer.

139 An engine pumps water from a lake to a high reservoir. To raise 200 gallons of water 300 feet above the lake the engine uses up (burns) one pint of diesel oil.

a. How many pints of oil would be required to pump 400 gallons to a height of 300 feet?
b. How many pints to pump 200 gallons to 600 feet.
c. How many pints to pump 400 gallons to 600 feet.
d. How many pints to pump 600 gallons to 450 feet.
e. If 1 gallon of water weighs 10 lb how many foot-pounds of energy does the engine provide when it uses 1 pint of fuel?
f. Not *all* the energy of the fuel goes into raising water. Suggest two or three ways in which energy is 'wasted'.
g. In what form does 'wasted energy' finally appear?

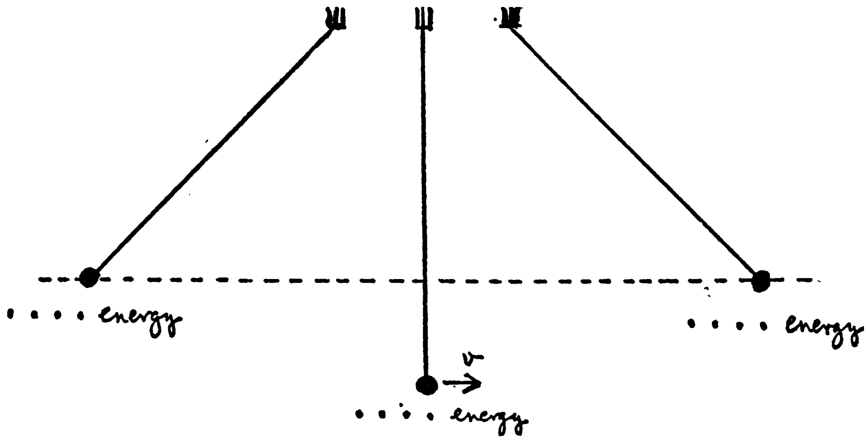


Figure 140

140 The diagrams, figure 140, show three positions of a swinging pendulum bob, the two extreme positions on either side, and the central position where it is moving with the maximum speed v. Each diagram is drawn to represent either motion-energy or

uphill-energy. Copy the diagrams and write in the correct word in each case.

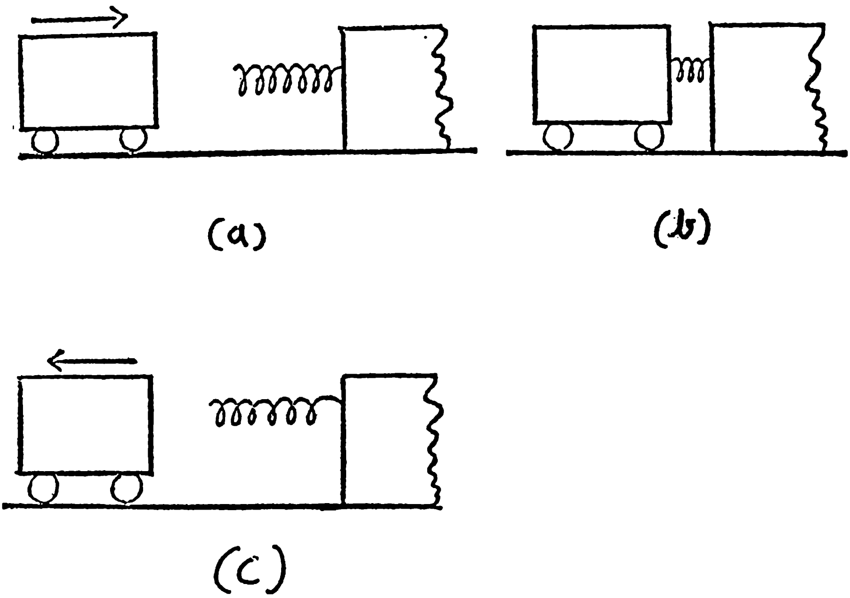


Figure 141

141 Copy each of the three diagrams in figure 141 and label it either 'motion-energy' or 'springs-energy'. Then write two or three sentences telling what energy changes take place when 'truck hits buffers'.

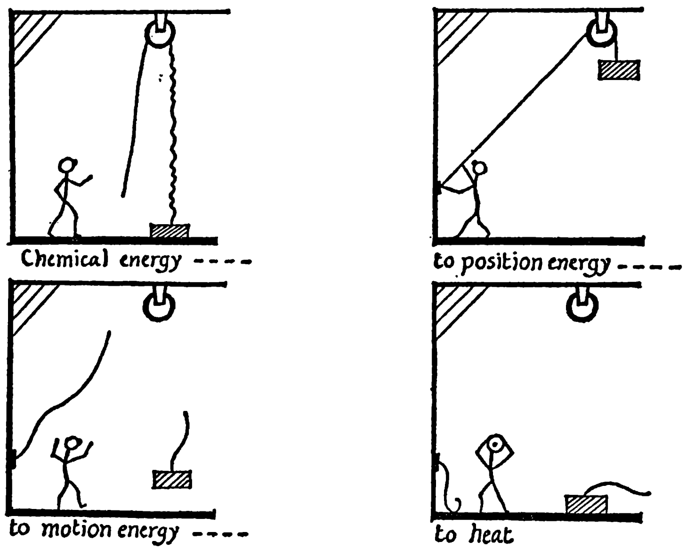


Figure 142

142 What has happened to the man and the rope and the weight, in figure 142, is clear enough. You are asked to write *four* sentences explaining the *energy changes* that have taken place.

143 When jobs are done, energy is converted from one form to another. Often there is a sequence of several changes. As an example, when an electric bell works from a battery:
Chemical Energy in the battery ⟶ electrical energy ⟶ mechanical energy in the vibrator ⟶ sound energy (and heat energy in the gong).

Copy out the following 'jobs' and underneath write the corresponding energy changes.

a. Magnesium is burnt in air.
b. A falling weight spins a dynamo which lights a lamp.
c. Methylated spirits burns in a model steam engine, which drives a generator, which lights a flash-lamp bulb.
d. A fast-moving car is brought to rest on a level road by use of the brakes.
e. I wind up a clock-work train and then allow it to run round the track until it comes to rest.

f. An archer shoots an arrow into a distant target.
g. A cricketer in the outfield throws in the ball, which is caught by the wicket-keeper without it bouncing.
h. Light falls on a photographer's exposure-meter and the needle moves across the scale.

144 Consider section (*e*) of the previous question rather more carefully. The train moves in three stages:

(*i*) starting from rest, it goes faster and faster until it reaches its maximum speed;
(*ii*) it does several laps of the track at a steady speed;
(*iii*) its speed gradually falls to zero.

Write a sentence or two about the energy changes which are taking place during each of the three stages.

145 Ordinary fuels, like coal or petrol, represent a store of energy. It is often convenient for us to make our own store of energy in some suitable form for use when required. For instance, the spring of the clock-work train in question 143(*e*) or the bow used to shoot the arrow in question 143(*f*). Try to think of two other ways in which we store up energy for our own convenience, and write a sentence or two about each example. There are at least two very common examples, and other less-well-known ones which are becoming very important. (If you cannot think of examples you can choose from four given at the end of this book.)

146 Write out the following statements, filling in the blanks with the words 'work' or 'energy' according to which you think is correct.

a. Fuels are stores of usable . . . which men and machines use up when they do some kinds of useful jobs, e.g. lifting weights.
b. The product (force) × (distance moved) is called . . . .
c. . . . shows the amount of . . . transferred from one form to another form or from one place to another place.

147 *Difficult*. Imagine a hole has been made right down through the centre of the Earth and out to the other side. What do you think would happen if you released a brick and allowed it to fall down the hole? Give two answers, saying what would happen:

a. If the Earth were like the Moon and had no atmosphere (air) at all.

b. If the hole is full of atmospheric air (you can assume that the brick does not touch the sides of the hole).

Also say what energy changes take place:

c. If the brick falls into an empty hole as in (*a*).
d. If the brick falls into a hole full of air as in (*b*).

148 *Work* is a measure of the amount of energy transferred. It is calculated from (force) × (distance moved). But we must be very careful that we know what we mean by 'distance moved'. Here are two problems with two answers to each. Show that *you* understand what is meant by 'distance moved' by writing down the *right* answer to (*a*) below – is it 78 ft. lb-wt? Then say why it is *right*, and why the other answer is *wrong*.

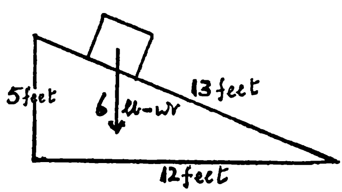


Figure 148(*a*)

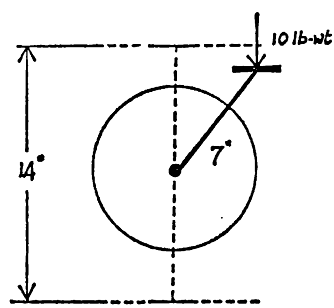


Figure 148(*b*)

a. A 6-lb block slides down a very smooth slope. The distances are shown in figure 148(*a*).
Uphill-energy transferred to motion-energy

= work

= force × distance moved

= *either* (i) 6 lb-wt × 13 ft
= 78 ft. lb-wt

or (ii) 6 lb-wt × 5 ft
= 30 ft. lb-wt

Now do the same for (*b*): say which answer is *right*, and say why it is *right* and why the other answer is *wrong*.

b. The rider of a bicycle pushes the pedal from 'top dead centre' to 'bottom dead centre' with a steady push of 10 lb-wt all the time. The length of the pedal crank is 7 inches.

Chemical energy (orginally in the form of food) transferred from cyclist to machine

= work = force × distance moved

= *either* (i) 10 lb-wt × 14 inches = 140 in. lb-wt.

= *or* (ii) 10 lb-wt × semicircular distance through which the pedal moves.

$= 10$ lb-wt $\times \frac{1}{2} (2 \times \frac{22}{7} \times 7)$ in

= 220 in. lb-wt

Now write the following sentence and add a few words at the end in order to make quite clear what is meant: 'Work (energy-transfer) is equal to the product of force and the distance moved . . .'

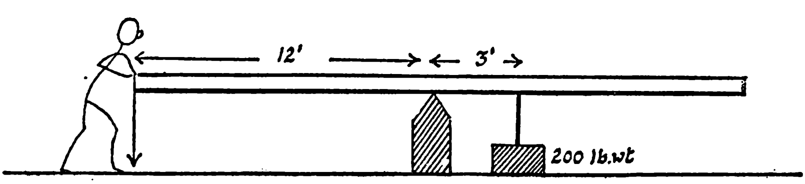


Figure 149

149 A man uses a long plank to lift a heavy load. He arranges the plank across a pivot (as in figure 149). By pushing downwards with an effort of F, he can just lift a load of 200 lb-wt.

a. How big must the effort F be?
b. How many times bigger than the effort is the load?
c. If the plank swings on the pivot so that the effort moves down 1 foot, how much energy is transferred from the man to the plank?

d. How far is the load raised?
e. How much energy is transferred from the plank to the load?
f. A gain of force is found in (*b*). Is there any gain or loss in energy?

150 If the pivot of the plank (in question 149) were in the form of a rather rusty steel rod fixed to the plank and running in holes in two rusty steel plates, what difference would it make to the above answer? Take each answer in turn and guess some suitable figures. What is now your answer to (*f*)?

151 A force of 1 lb-wt is the force with which the Earth pulls on the lump of metal we call a pound. Scientists use a unit of force called a *newton* which is roughly the same as a $\frac{1}{4}$ lb-wt. To pick up a 100-gm object you will need to exert a force of roughly 1 newton. If, by exerting a force of 1 newton, you raise the object through a distance of 1 metre you will have *transferred 1 joule of energy* from chemical energy in your body to position-energy in the object.

In each of the following cases say how big an energy change takes place and what happens in sentences, such as, '25 joules of position-energy are transferred to motion-energy'.

a. An object which the Earth pulls with a force of 7 newtons falls through a vertical distance of 3 metres.
b. A man lifts an encyclopaedia (force acting on it 50 newtons) from a table of height 0·8 metre ($\frac{8}{10}$ metre) to the top shelf of a bookcase at height 2 metres.
c. A man pushes a car with a force of 300 newtons, causing it to move steadily along a horizontal road for a distance of 50 metres.
d. A 110-lb boy falls from a height of 12 feet on to a trampoline (a kind of spring mattress) and rebounds to a height of 6 feet. In this case make estimates of the energy changes (in joules), using rough equivalents between the English and the scientific units.

152 A 70-kilogram man climbing a mountain can climb 500 metres vertically in one hour.

a. How much position-energy (in joules) does he gain in four hours' climbing?
b. Assuming that the human body is capable of changing one-quarter of the chemical energy drawn from a man's own supply into useful mechanical energy delivered by the muscles, how much chemical energy does he use up in four hours' climbing?

c. How much extra heat energy does he have to get rid of in four hours, as a result of climbing? (This is in addition to the heat energy he would have lost had he stayed still all the time.)
d. He will have to make up for the chemical energy used up (answer (*b*)) by eating more food. Yet, when he walks down the mountain he loses all the position-energy he gained. Why then, does he need extra food for mountain climbing?

Note: *Suggested 'examples' for question 145.*

Winding up the mainspring of a watch.

Raising the weight of a grandfather clock.

Using energy from an accumulator battery to turn the starter-motor of a car.

Operating a pile-driver, i.e. using a diesel engine to raise the weight used to drive in the 'pile'.

Organizer Professor E M Rogers

Associate organizers J L Lewis E J Wenham

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This book has been prepared by
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